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STA To Expand High Performance Superdiamond Research

95FE0105 Tokyo KAGAKU KOGYO NIPPO in Japanese 4 Oct 94 p 1

[FBIS Translated Text] The National Institute for Research in Inorganic Materials (NIRIM) (Director: Yoshinori Fujiki) of the Science and Technology Agency has announced its FY95 plan to expand and strengthen the research project concerning the "functional superdiamond" that is regarded as the next-generation highly functional electronic material replacing the silicon semiconductor. This decision was made in connection with the anticipated December 1994 completion of the new building for the Advanced Functional Material Research Center, where the entire superdiamond research project will be pursued. The project will primarily aim at developing technologies for preparing single crystalline diamond films and cubic boron nitride (cBN) thin films with a structure similar to that of diamonds. In addition, many facets of studies, more sophisticated than ever, will also be carried out. As soon as the building is completed, large research facilities will be gradually installed, and new researchers will be hired. The Center has requested its FY95 budget of ¥250 million.

The implementation of silicon semiconductors has expanded to ICs, LSIs, and super-LSIs, which have now become indispensable materials in various industries. However, the semiconductors are not stable enough against heat, radioactive rays, or chemicals to further expand their applications or to further improve their performances.

On the other hand, superdiamond has strength and thermal conductivity that are both 10 times greater than that of silicon and an emission energy that is six times greater than that of silicon. In addition, superdiamond has excellent resistance against radioactive rays and heat. Therefore, superdiamond is expected to enable further increases in the degree of integration for super-LSIs and to be implemented under extreme conditions, including space and nuclear power plants. In FY93, NIRIM initiated the five-year project in an attempt to develop highly functional materials from diamonds and cBN thin films.

One of the problems to be solved before a functional material can be made from diamond films is the establishement of the single-crystalline film synthesis by epitaxy. Here, epitaxy is defined to be the method of synthesizing a single-crystalline diamond film with oriented crystalline directions on a non-diamond substrate. Thus far, such single-crystalline films have only been satisfactorily synthesized on diamond and cBN substrates. In the superdiamond project, efforts will be made to establish a set of synthesis conditions to obtain more nearly perfect epitaxial films on substrates of silicon, nickel, and cobalt, which were found to permit the synthesis of partial epitaxial growth of single-crystalline diamond films.

Several methods are available for the synthesis of cBN films. They include the chemical method of forming a film through a reaction involving the excitation of a substrate's surface with light; the physical method of preparing a film by exciting a substrate's surface by ionic bombardment; and the atom/molecule-control synthesis method of building a film by arranging one crystal layer at a time on a substrate through the irradiation of a beam (molecular beam) of raw material gas. In the project, various synthesis methods will be tried to improve the quality of cBN crystalline films. Unfortunately, the research level in this field "has not yet reached that of the diamond film synthesis," according to a NIRIM spokesperson. The plan is to utilize a surface excitation synthesis device, which is to be newly installed, for optimizing the synthesis method to prepare high-quality crystals.

Software Houses Moving From Subcontracting To Lateral Contracting

95FE0338A Tokyo NIKKEI COMPUTERS in Japanese 6 Feb 95 pp 87-93

[Article by Aoki Shinichi]

[FBIS Translated Text]

- Software houses, including both major manufacturers and small and medium businesses, have begun to move towards a lateral cooperation in order to do away with subcontracting. Software houses, strong in specialized fields, are grouping together to help users by moving to lateral contracting which provides a collection of essential technology from each of the software houses.
- Software houses are driven by the needs of specialized fields in order to deal with the changes in technology and the market. Lateral contracting has the capability of dispersing the risks that accompany specialization. The increase in demands of open systems and small scale systems is also a reason for the change.
- However, if only software houses in a specific specialty group together, lateral contracting will not succeed. The improvement of the capability of users to make suggestions and the management over many software houses is the key.

In 1993, Metatech (headquarters in Tokyo, President Tetsuya Toyoda), which is strong in communication controls, and ASA Systems (headquarters in Kitakyushu, President Asagami Shuntai), which specializes in FA (Factory Automation), began mutually exchanging information. This exchange has been over the phone as well as by using computers connected to phone lines.

The aim is to obtain system orders by having both companies mutually supplement the software package. ASA offers CAD (Computer Aided Design) software for personal computers and work stations. Metatech offers facsimile communication software. When the data transmission portion is made, the system for transmitting by facsimile the drawing made on the CAD is finished.

In 1994, a system was delivered to Bridgestone's Yokohama Plant, and presently, many business activities are being promoted. Of the orders received, the majority are for many millions of yen, with the large orders reaching ¥20 million. According to Miyoko Takemata, Metatech's SI Technology Sales Manager, "In 1995, it appears that there will be six to seven orders received." In the fall of last year, Japan Techno Lab (headquarters in Tokyo, President Eisei Matsumura), which specializes in image processing, was added to this circle, and thus a further increase in the number of orders is projected.

Specialty Fields Unite to Receive Mutual Orders

Software houses which have been hurt by the recession cannot stay in business unless they find new business opportunities. As a solution, software houses working in specialized fields are, for the first time, working together and cooperating. The software houses are mutually promoting consulting and support business, and are creating new order opportunities for new system development items. There are many examples of independent and small and medium-size software houses combining their specialized, essential technology and succeeding in obtaining mutual orders.

In the fall of last year, Ratokku Engineering (headquarters in Tokyo, President Shushi Nango), which specializes in picture analysis and recognition, and M-Ken (headquarters in Tokyo, President Aki Inoue), which specializes in AI (Artificial Intelligence), combined their neuro technology and received a system order from the Tsukuba Medical Center in Ibaragi Prefecture. It is a picture analysis system for X-rays, etc. With this as a start, not only was an order received for neuro technology, but an order is in the process for the medical center facilities for a picture analysis system which uses chaos technology. Ratokku's President Nango stated that, "Right now the scale is small, but cases where numerous software houses unite and mutually propose a system should increase."

Even Independent Major Manufacturers Are Beginning to Unite

This type of alliance with software houses does not stop with just the small and medium businesses.

In the middle of February of this year, software houses of independent leading manufacturers began to cooperate as well. It is called the "Information Technology Alliance 21" (abbreviated ITA 21). Argotechnos 21 (headquarters in Tokyo, President Yujiro Sato) acts as the center and will address the independent software houses. Twelve to thirteen companies are expected to unite.

The participating software houses will throw out all existing policies and will take on a management strategy which is specialized for their sector. Four sections will be prepared for management, engineers, salesmen, and for the members of administration. The plan calls for gathering information regarding management, technology, etc., and mutually supplementing and sharing essential technology and know-how between the members, thus promoting cooperative business for the development of new product packages and tools and for receiving large-scale system orders.

President Sato of Argotechnos stated that, "This differs from the present friendly organizations of the industrial world. Not only is information exchanged, but marketing and technology flow is cooperatively promoted. We want to have a management capability as if it were one company."

Aiming at Subcontracting Through Lateral Contracting

This type of cooperative business structure between software houses differs from subcontracting and is called

lateral contracting. It is aimed at breaking away from the former management structure which held orders from hardware manufacturers and leading system integrators.

Until now, software houses have been in a position which resembled laborers working for a master contractor who supervises a construction site. The work is difficult, but sales efforts are not necessary. If they can wait for a job from a subcontractor, it is perfect. However, when investments continue to be sluggish for information, jobs come to an end. Even if orders come, the unit price would be pushed down so low that it was not uncommon to hear it said that they were working for free.

Software houses with specialized technology which hardware manufacturers do not have, are not seeing a reduction in jobs, and the influence due to a reduction in the unit price is small. The chance of them surviving as specialists is high. According to President Sato of Argotechnos, "Even with this, I do not anticipate growth of the industry while we are dangling from subcontractors."

In contrast, with lateral contracting, a number of software houses group together and are in direct contact with the user and receive orders. Each software house is then responsible for the portion of the order for which it specializes in. Differing from subcontracting, because the master contractor does not take a large margin, the profit can be enjoyed by the software houses.

There have been organizations with the purpose of obtaining joint orders and services such as the Medium and Small Software House Cooperative Association and Research Society. The idea is that by having the Association and Research Society act as the contact, it is possible to receive orders for relatively large-scale systems. However, at present, there are virtually no organizations functioning for joint orders. The effects of not being able to produce new capabilities for the customer by just grouping companies are being felt.

Even if a lateral organization is used, it is difficult for an independent software house with no assets to receive orders for large-scale systems which require an investment of many billions of yen. However, small and medium-size systems are possible. Mr. Seido Kubota, Finance and Management Section Leader of the research center of Mitsui Information Development (headquarters in Tokyo, President Shuji Maruyama), forecasts that "if small and medium-size software houses can quickly construct actual systems, they will have a better chance than hardware manufacturers at receiving orders."

Lateral Contracting Changes the Structure of the Industrial World

"Using the construction of a house as an example, building a roof or the walls would be a specialty as would the foundation construction be a skilled area. Just like this, it would be fair to promote a job by dividing certain responsibilities among software houses which specialize in a certain area." Iwao Tojo, president of Surigiken (headquarters in Tokyo) which is developing business activities aimed at receiving mutual orders for four companies, emphasizes the significance of lateral contracting. President Sato of Argotechnos also states, "The time has come to aim for mutual cooperation where the business strategy is thought of in terms of each specialized software house contributing its knowledge." This type of conscious effort is the driving force to turning towards lateral contracting.

In lateral contracting, the relationship between each software house is equal. The members which compose the group all have sales business packages, and each is a software house with specialized technology which can't be imitated easily by hardware manufacturers. It is not just a mere programming contract. Hence, lateral contracting is drastically different from the former pyramid-shaped organization of subcontracting which places major hardware manufacturers and major system integrators at the peak.

Lateral Contracting Results in Quick Construction of a Reliable System and Allows Software Houses to Handle an Increased Amount of Workload

There are many advantages which are a result of lateral contracting. The first is that a very reliable system can be constructed in a short time period.

The system for Bridgestone's Yokohama Plant which Metatech and ASA Systems worked on was completed in approximately one month. Mr. Takemata, manager at Metatech, stated that, "If one company had independently built the system, it would have taken nearly a year." If a system can be constructed in a short time frame, it is possible to handle a larger amount of work.

If a system is constructed in a short time frame, personnel expenses can be reduced, and the expenses for the customer can also be lowered. Furthermore, end users selecting systems which aren't dependent on their own company's information systems or hardware manufacturers, brings many opportunities to independent software houses.

Package Development Through Feedback

The second advantage of lateral contracting is that there is feedback on technology and know-how. When one software house independently tries to increase its package product line, development costs, manpower, etc. become a problem. However, in lateral contracting, technology feedback and essential technology from other companies is combined, and thus a new package can be relatively easily developed.

Comtech (headquarters in Sendai, President Eishi Shitsuhata) is having several software houses improve its own package to a form which is specialized for a certain type of industry and is promoting the development of a lateral contracting organization with a mutual product.

The strategy is to increase the amount of orders received using this improved package as leverage. Each software house independently develops its own sales activities. When it is time to construct a system, if one company does not have enough manpower, personnel can be borrowed from other software houses which have a surplus.

In January of this year, Comtech mutually agreed with Fuji FACOM Controls (headquarters in Tokyo, President Kunihiko Sawa), a control devices manufacturer of Fuji Electric, to mutually cooperate in the development of a system. The source code of Comtech's integrated package CIRCUS will be disclosed, and Fuji FACOM Controls will develop the production control portion. This will be combined with CIRCUS and then sold as a mutual product directed at customers in the manufacturing industry. In addition, the strengthening of the mutual product line is hastened by having Mitsutani Industries (headquarters in Kanazawa, President Michiru Mitsutani), a chemical products trading company, develop packages for motels and hotels.

Full scale cooperative sales of a package developed by small-scale software houses in the Tokyo metropolitan area affiliated with the Cosmosoft Cooperative Association (headquarters in Tokyo, Representative Director Masawa Dainichi), also began in November of last year. Within the association, nine companies arranged in a relative sales structure are the center. By combining a package which is mutually owned, these companies are trying to obtain new orders. There is a plan to start sales this spring through an association brand.

Openness Is Boosting Lateral Contracting

When several software houses have a mutual product, the risks of being in a specialized niche in a market are dispersed. (Chart 4)

Chart 4. Merits for software houses resulting from lateral contracting. There is a strong possibility that the present problems faced by software houses can be resolved.

Business Problems of Software Houses	Risks	Merits of Lateral Contracting
Expansion of businesses specialized in a specific field.	If the market is saturated, the business will not grow, and there will be no future expansion.	Each software house mutually supplements one another with information in their specialized area and thus new business opportunities develop.
Engineers and development resources can't be increased.	Technology strength may taper off.	Engineers are transferred between each company as needed. New tools and packages can be developed mutually.
Pressing need for intensification of the sales strength.	Only information for the specialized field can be obtained.	If each company contributes its sales information, chances are greater for obtaining new customers.

The change in computer technology is rapid from year to year. System construction has become very complex, and it is becoming rare when one company can independently handle a system. As a countermeasure, the only thing that can be done is concentrating business resources in a strong field, and by thoroughly delving into that field, establishing superiority. But, if a specialized market reaches its peak, there is the future worry that it will taper off.

However, if a company can be in several niche markets, there is an adequate number of potential customers. Increasing the product line in the package products broadens the range of customers.

This is not the circumstance of only the software houses, open systems also are dealing with lateral contracting. It is virtually nonexistent in mainframe hardware technology. They are separating from manufacturers, and the groundwork is being done for joining with software houses. President Tojo of Surigiken indicated that, "Like general purpose engines, it is not necessary for one company to make the entire thing from the start. That is nonsense."

Cases of Lateral Contracting With Dealers As Well

Like Miroku Information Services and the leading software house Sodo Business Systems (abbreviated SBS, headquarters in Tokyo, President Mitsuo Tsubouchi), there are many cases where the dealer and the software house have joined hands. Miroku Information Services offers a financial package which runs off of its exclusive "off control" system. SBS offers a package for sales control, personnel management, etc. which operates on UNIX. In July of last year, they were successful in receiving the first order using this method. It was the Finance, Sales Division System of Akashi (headquarters in Yokohama, President Yoshimitsu Torikoshi), the leading manufacturer of precision testing devises.

The system for this company was constructed 10 years ago with Mitsubishi's off control MELCOM as a host device. The system was obsolete and NEC suggested reconstructing the main system which used "off control" as a host device. However, their results were getting worse at Akashi and it became a priority. Here, Mirokku Information Systems and SBS were aggressive and were successful at receiving an order for a new system. "If the system was to be rebuilt, it would have required a great deal of time and investment. Both of these companies had a great deal of actual sales results of their packages. Because they can construct the system in a short period of time, we decided to let them have the job." (Akashi)

In January of this year, an order was received from a traffic control company by using the same method.

Miroku Information is promoting the open system equivalence of the finance package and examining a system proposal which does not use an exclusive device. President Tsubouchi of SBS is very enthusiastic and stated that, "Until now we have had many jobs from Toshiba. However, if the chance arises to work with mutually cooperating businesses, I would like to promote it."

Lateral Contracting Conception In Package Development As Well

The basic idea behind lateral contracting is, if another software house has essential technology which surpasses your own, you should use it thoroughly. Businesses are appearing which are developing packages by combining technology and know-how from other software houses.

Work flow control software, "LAN Venture Group Ware," released last July by Lancept (headquarters in Tokyo, President Yuko Matsuhara), is one example. Business packages sold by other software houses in different industries were combined. The only part developed in-house was the gateway portion which controls the work flow by message communications.

The sales control and finance management packages of PCA and Obick Consultants (headquarters in Tokyo, President Seishi Wada), and Milkyway (headquarters in Tokyo, President Sugumoto Yoshii), were used. "Because we used the marketing package, the bag was small, and we were able to keep the price down." (President Matsuhara).

Lancept was just established in January of last year. President Matsuhara himself is specialized in communications, but the majority of the employees are just laymen when it comes to business applications. Even with this, they were able to deliver to seven customers last year. President Matsuhara stated that, "Because we used packages with actual results, it was easy to obtain the customers trust."

On the other hand, there are software houses such as Manage Business (headquarters in Machida City, Tokyo, President Shin Tsunogawa) which promote the development of packages for the international division. In the fall of last year, this company cooperated loosely with two overseas software houses and developed a middle ware.

The two companies Manage Business worked with were PSI Data Systems (Bangolore City), the leading information service manufacturer in India, and Lakeview (headquarters in Chicago), a leading American software house. The two overseas companies were in charge of ideas and the basic design. Manage Business translated it into Japanese and did the sales. The coding was done by MM Shanghai Development Corp. (Shanghai City), a Chinese joint venture company with Manage Business. The exchange of data between these companies was done on Internet. Dr. Kobayashi, Business Promotion Manager, said that, "The construction cost was 40 percent less than if it had been independently developed by our company. Even the development time was shortened by 30 percent."

Stipulations for Lateral Contracting To Be Successful: Packaging and Management Capability

Lateral contracting is an effective measure for solving the various problems which software houses have. However, it is not sufficient for specialized software houses to just group together. In order to succeed, there are several points which must be met.

Core Technology Must Be Packaged

It is understood that each software house has core technology and is in a specialized field. However, it is important to package the applications which are the core. By being able to construct a system with the smallest limits, a fast, reliable system will follow.

Shojiro Nakamura, director at Comtech, stated, "Even if there are actual development results for orders received in the industry, it is difficult to persuade the customer with only know-how. However, if it is a package, when suggesting a system, a demonstration can actually be shown to the customer and it has much appeal." If it is a package which has had many upgrades to the version, there is little chance of trouble, and if trouble should occur, it is very clear which software house holds responsibility.

Joint Ownership Disclosing the Sales Information

In expanding new ideas, it is necessary to promote aggressive sales activities. In order for this to occur, the participating software houses disclose their sales information. The reason that cooperative associations and research societies, which work for the purpose of receiving mutual orders, do not function well, is because joint ownership of information is insufficient.

In order for there to be joint ownership of information, it is necessary to maintain an infrastructure for information communication. If the other software house which you are cooperating with is in a distant location, this is all the more important. Metatech and ASA Systems are using their personal computers hooked to phone lines to exchange sales information and specifications manuals. Like Raimoshi Network (Taiko Iibashi, Representative Agent), which is composed of seven small-scale software houses, there are places providing an exclusive bulletin board for sales information during communication on personal computers. However, the sales force meets periodically. The majority have decided to use facsimile as their window for communication.

Furthermore, it is desirable to have the development tools and language for system construction standardized. If the tools are standardized, the productivity of system construction is elevated. The group of Comtech, Mitsutani Industries, and Fuji FACOM Controls, is using the same development tool, ACCELL of America's Oracle.

The Problem of Lack of Management Strength

If we are to move to lateral contracting to promote mutual orders, the most important thing is the management strength for system design and project control. In lateral contracting, there is a great deal of exchange with not only the customer, but also between the cooperating software houses. When there are two or three companies working together, it is not an enormous load. But when you reach the scale of five or more companies working together, there is a great need for a coordinator. But in software houses other than the leading ones, it is difficult to find personnel with this type of ability.

Seiyo Shimomura, vice president of DIT (headquarters in Tokyo, President Yoshiko Imamura), which specializes in the design and construction of LAN (Local Area Network), expressed his dissatisfaction. "There are plenty of software houses with technology strength, but when they are entrusted with building the application portion when constructing a LAN, they can't manage the project well. Even if they are well known, they are far from the standard that we would hope for." As Takeo Shimojo, president of Japan Computer Dynamics (headquarters in Tokyo), indicated, "They don't have the management know-how for joint businesses." This type of negative feeling is widespread for software houses involved in lateral contracting.

Companies With Coordinators Are Expanding

From this condition, according to Mr. Kubota, manager at Mitsui Information Development, "We are hoping that companies which have the ability to act as coordinators for both management and sales will appear." Thus, consulting companies have been formed to make coordinating a business. Even software houses are beginning to establish companies which specialize in management.

Relation Development Laboratories (headquarters in Tokyo, President Kobashiko Hara), a leading consulting company, has called for the union of software houses, and in June of last year, established the "Solution Business Promotion Project Team." It's aim is to offer consulting for the management conditions of its clients and contract for construction of an information system which supports the business reforms.

Relation Development Laboratories oversees consulting, while the group of software houses is in charge of detail design and system construction. Both parties cooperate on the basic design. Sales activities are underway by tightening the consumer electronics distribution. In addition to IX participating in July of last year, the leading manufacturer, Hitachi Software Engineering, also joined in September. Hitachi Industries also participated as a hardware vendor.

IX dedicated two people, senior system engineers, full time. They are working together with Relation Development Laboratories on business analysis and basic design. Presently, negotiations are under way with four consumer electronics companies. A group is being promoted which has companies strong in business packages as a center.

On the other hand, Relation Development Laboratories is expediting the union of consulting companies. The project control method is not established, and there are many questions, but the plan is "In the future, we will have cooperative businesses like Zenkon (an overall construction company) where construction is done by gathering together many companies and dividing the responsibility for the large buildings." (President Hara, Relation Development Laboratories).

Within software houses as well, companies are being established with the main duty of coordinating lateral contracting.

Mr. Katsuro Kinoshita, president of Aurora System Design Offices (headquarters in Yokohama City), is the focal point and is pushing the plan for the SIOS Controls Company. SI stands for system integration and OS is an abbreviation for out sourcing. SIOS Controls Company will perform the following duties. It will oversee business analysis and system design, while the system integrator or the software house is responsible for selection of hardware and actual system construction. In addition to auditing and managing the progress condition of the project, it will be involved with tests during actual operation.

Aurora System Design Offices is in the process of recruiting approved software houses and consulting companies. UNIX Business Association (abbreviated UBA), a voluntary group of small and medium software houses which build systems on UNIX, is advancing with preparations for establishing a company under the name of "Business Center" based on President Kinoshita's idea.

Both Aurora Systems and UBA are examining the direction of software houses which make up the lateral contracting organization, contributing investments, and establishing a company. The software house will jointly contribute manpower as well. The manpower collected from each of the software houses will be SE (Systems Engineers) with a great deal of experience with projects and the ability to analyze duties. The aim is to obtain systems engineers over 40 years old who have much experience with the management problems of software houses.

The director of UBA, President Tojo of Surigiken, makes the comparison, "It will become a company which fulfills a duty like that of a mast carpenter." Aside from the member software houses, UBA is calling for the participation of accounting offices and management consultants. If all goes well, the "Business Center" should be established sometime this year.

At present, lateral contracting is still just a small ripple. However, if this type of consulting company continues to grow, the small ripple will become a large swell, and the software world will become very different from what it is today.

DRAM Battlefield: Victory Depends on 16M Shrink Version

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[FBIS Translated Text]

Overview

Victory in the 16M DRAM business will depend on how soon a mass-produced version of the chip, which provides a favorable cost advantage, can be made. With this aim in mind, the various DRAM makers are stepping up efforts to build new production lines to begin volume production by the end of 1994 and into 1995.

Companies which are taking the lead in shrinking chip size will ship third-generation versions $70mm^2$ or smaller as early as December 1994. Even those companies which are behind will enter the market with second-generation versions which are $100mm^2$.

The stacked type cell technology continues to be used to achieve these newer versions, but there are two major types now being used—the fin construction and thick-film construction. Manufacturing companies will sharply expand production capacity throughout 1995 three to five times current capacity. Some companies will even reach production of 6.5 million chips per month by the end of 1995. The time when the bit unit price reverses that of the 4M generation is approaching soon, thus heightening the desire for systems-oriented products. Chip capacity is expected to increase even further with the introduction of new operating systems for the personal computer. Although the supply of production equipment for increased DRAM production is a bit behind, it appears that this will not be a serious problem.

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Part 1. Selection of Technology

Introduction of Third-Generation Versions, and Use of Fin and Thick-film Constructions; Cost Advantage Provided by $70-85mm^2$ Chip

DRAM manufacturing companies are poised to enter serious mass production of a shrink version of the 16M DRAM. Companies which are ahead plan to ship third-generation versions with a chip size of $70mm^2$ or less before the end of 1994. Even those companies which are farther behind will produce second-generation versions that are about $100mm^2$ in size before the end of 1994.

The companies have changed the cell configuration, and done as much as they can to simplify processing in order to achieve a competitively priced chip. There are now two types of stacked cell configurations. One is a **fin design**, and this type is likely to continue into the 64M generation. The other is a **thick-film** design, which can be used with many of the same processes used for the 4M generation. Use of the simple trench design without modification poses a challenge to the shrink version. Companies are taking action to avoid processing of complex line constructions.

The major DRAM manufacturing companies both in Japan and abroad are developing a shrink version 16M DRAM chip which is headed for mass production. (See Figure 1.) The forerunning companies will ship third-generation versions before the end of 1994, gambling that the competitively priced chip will prevail in the 16M market.

To achieve a chip of this nature, the manufacturing companies are simultaneously promoting small cells and simplified processes. Although the stacked type of cell is the main type used, there are two general shapes used for the storage node, where electrical charges are stored. All of the companies are headed away from processes which use hole-embedding technology.

Third-Generation Version

Currently, the DRAM makers' attention is focused on how fast they can get a competitively priced chip to the market.

Since the 16M generation, the first generation version has frequently been used as a "probe chip" to test the demand for performance and capability in the market. The second generation version which was shipped in 1992-94 was sealed in a package 300 mil wide (1 mil is 25.4μ). In this way, the major leading companies could achieve a production level of 1 million chips per month. For the third generation version, introduced in 1994-95, production of several million chips per month is anticipated during 1995-96. Cost competitiveness, determined by how small the surface is, or how simple the processes are, will be the key factor in its success.

The chip size for one-word and four-word standard chips diminished from $130mm^2$ for the first generation, to about $100mm^2$ for second-generation chips. A $200mm^2$ wafer will theoretically yield about 250 chips. The size will shrink even further for the third generation, down to about $85-70mm^2$. For the $85mm^2$ size, the yield per wafer will be about 300 chips; for the $70mm^2$ size it will be about 370 chips. This means that the yield will increase 20 to 50 percent compared to the $100mm^2$ chip size.

Hitachi, Samsung, and NEC Take the Lead

The shipping period for the third generation version can be classified into three groups. The leading group will

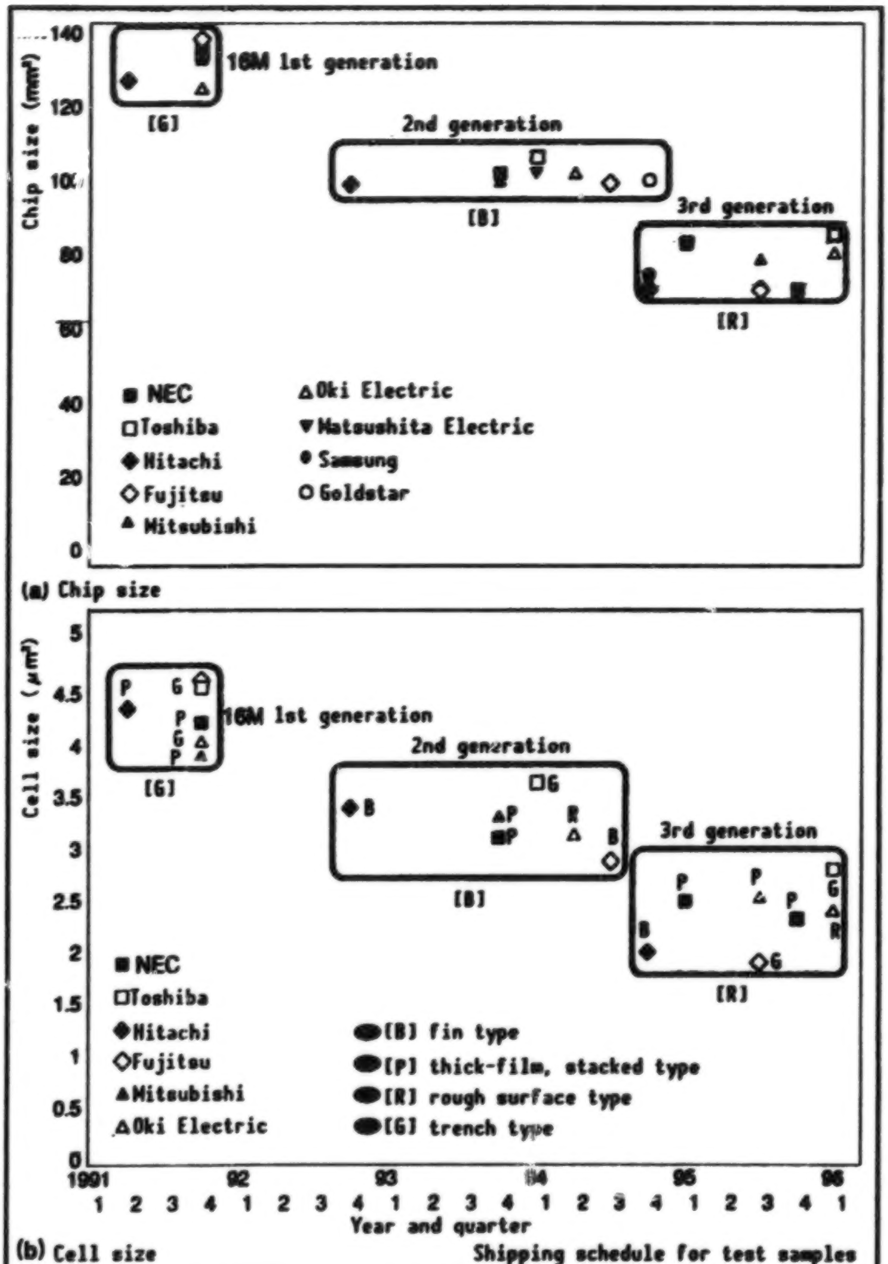

Figure 1. Transition in the Sizes of Cells and Chips. Mitsubishi has a 120mm² chip with x1, x4, x8 configuration, and its 100mm² chip was originally considered as the third generation version. However, since it is the same size as second generation versions made by other companies, it was included as second generation here.

begin shipping in December 1994 or January 1995. The second group will begin shipping during 1995, and the third group will begin shipment in 1996.

The leading group, which is most actively involved in producing the shrink version chip, is made up of Hitachi Ltd., Samsung Electronics Co. Ltd. of Korea, and NEC. Hitachi, which began shipping the second generation version in the fourth quarter of 1992, a year earlier than other companies, has already completely switched over to volume production of the second generation version. Hitachi plans to ship a chip that is less than 70mm² by the end of 1994. Samsung, which is currently the fore-running mass producer of the 16M DRAM, plans to sharply boost its production capability, targeting the

shipment of a 70mm^2 chip by the end of 1994. NEC will put out an 82.6mm^2 chip at the beginning of 1995 and a smaller 70mm^2 version sometime during 1995.

The second group of manufacturing companies consists of Fujitsu and Mitsubishi Electric. Mitsubishi, which produced a second generation version 99.8mm^2 at the end of 1993, will ship a third generation version about 78mm^2 in size during the third quarter of 1995. Fujitsu, which shipped a second generation version 98.5mm^2 in size during the third quarter of 1994, plans to ship a third generation version about 70mm^2 in size during the third quarter of 1995.

The third group of companies consists of Toshiba, Oki Electric Industrial Co., and Matsushita Electric Industrial Company. Toshiba, which produced a second generation version 106mm^2 in size at the beginning of 1994, will ship a third generation version about 85mm^2 in size during the first quarter of 1996. Oki Electric, which produced a second generation version 102mm^2 in size during the second quarter of 1994, is thinking of shipping a third generation version about 80mm^2 in size at the beginning of 1996. Matsushita, which is currently shipping a second generation version 103.7mm^2 in size, will ship a third generation version in the second quarter of 1996.[Note 1)]

Note 1: Although plans for the third generation version are not clear, for the second generation version, Micron Semiconductor Co. of the U.S. began shipping a 96.1mm^2 chip during the third quarter of 1994, and Goldstar Electron Co. of Korea will begin shipping a 100mm^2 chip before the end of 1994. Samsung's newest plans for the 16M third generation version are shown here. They will ship samples in 1995, which is later than initially planned.

Cell Size Reduction and Process Simplification Pursued

To boost the cost advantage of the third generation version during mass production in 1995 and 1996, the manufacturing companies are promoting efforts toward both reducing the cell size and simplifying the processes required.

To secure the capacity for smaller cells, all of the companies are developing new cell structures. The design rule for the third generation version is about 0.4µm. For light exposure, a combination of i-line source and single layer resist is used. Like the 4M DRAM generation, the stacked type cell structure is the predominant type used. However, the shape of the storage node is now one of two different types. (See Tables 1 and 2.) The first is a fin-type storage node, where the rear side of the storage node is also used as an electrode. The other type is a thick-film type which has a thick node and provides capacity on the sidewalls. In addition, there is also a rough surface type which has a rough surface on the storage node.[Note 2)] The trench type uses a single trench without modification, and the cell structure does not change. This technique was used by DRAM manufacturers to shrink the cell size from the first generation range of 3.86-4.62µm^2, to the second generation range of 2.86-3.62µm^2. For the third generation, the size will be even smaller. For the 64M DRAM, cell size will range from 1.89µm^2 to 2.8µm^2.

Efforts to simplify the processing in order to heighten cost competitiveness focus chiefly on the wiring structure, which has been very complex in the past.

Table 1. Changing Cell Structures for DRAM Makers

	16M 1st Generation	16M 2nd Generation	16M 3rd Generation	64M 1st Generation
NEC	Stacked (thick-film)	Stacked (thick-film)	Stacked (thick-film)	Stacked (thick-film)
Toshiba	Trench (simple)	Trench (simple)	Trench (simple)	Trench (substrate cell plate)
Hitachi	Stacked (simple)	Stacked (1.5 fins)	Stacked (2.5 fins)	Stacked (2.5 fins)
Fujitsu	Stacked (1 fin)	Stacked (1 fin)	Stacked (2 fins)	Stacked (2 fins)
Mitsubishi	Stacked (thick-film)	Stacked (thick-film)	Stacked (thick-film)	Stacked (cylindrical)
Oki	Stacked (1 fin)	Stacked (rough surface)	Stacked (rough surface)	Stacked (rough surface + thick-film)
Matsushita	Stacked (thick-film)	Stacked (thick-film)	Stacked (thick-film)	Stacked (thick-film)
Samsung	Stacked	Stacked (1 fin)	Stacked (1 fin)	Stacked (cylindrical)
Hyundai*	Stacked	Stacked	Stacked	Stacked (cylindrical)
Goldstar*	—	Stacked (fin)	Not established	Stacked (cylindrical)
Micron	Stacked (simple)	Stacked (simple)	Stacked*	Stacked (rough surface + cylindrical)

*Estimated by the editors

Table 2. Various Process Technologies for Mass Production of 16M Chips

Mitsubishi is currently examining what level of capacitance it will use for its third generation version. For 30fF, the thick-film design will be used; for 40fF the single fin design will be used. For wiring technology, all of the companies are simplifying the embedding technique. Hitachi is adopting a three-layer metal construction. For exposure, Mitsubishi is developing a half-tone type phase shifting technique.

*Items marked with an asterisk are assumptions made by the editors.

Manufacturer		NEC	Toshiba	Hitachi	Fujitsu	Mitsubishi	Oki Electric	Matsushita Electronics	Samsung	Hyundai	Micron
Generation		3rd	3rd	3rd	3rd	3rd	3rd	3rd	3rd	3rd	2nd
Design rule (μm)		0.4	0.45	0.4	0.35	0.4	0.4	0.35	0.4	No response	0.5
Chip size (mm^2)		82.6	about 85	about 70	about 70	about 78	about 80	65	70	No response	96.1
Cell	Surface area (μm^2)	2.5	about 2.8	about 2	1.89	2.53	2.4	1.665	2.2	No response	2.61
	Capacitor Construction	Thick-film stack	Simple trench	2.5 fin*	2 fin	Thick-film stack or single film	Rough surface stack	Thick-film stack	1 fin*	No response	Simple stack
	Shield Construction	Yes	—	No	Yes	Yes	Yes	Yes	No response	No response	No
	Cumulative Capacitance (fF)	27	30	about 30	No response	30 to 40	25	25	30	No response	30
	C_B/C_S	8	No response	No response	No response	6	7	9	No response	No response	4.3
	Type of insulating film	NO	NO	NO	Nitride film	NO	Nitride film	NO	NO	No response	ONO
	SiO_2 conversion film thickness (nm)	5.5	6	about 5	No response	4.5	5	4.5	5	No response	7
	Gate length (μm)	0.45	0.45	0.4*1	No response	0.45	0.45	0.45	0.6	No response	0.55
Surrounding transistors	Oxide film thickness (nm)	14	12	about 10	No response	12 to 13	10	12	12	No response	15
	Isolation method	Improved LOCOS	Improved LOCOS	Improved LOCOS	Improved LOCOS	Improved LOCOS	Improved LOCOS	Improved LOCOS	SEPOX	No response	LOCOS

Table 2. Various Process Technologies for Mass Production of 16M Chips (Continued)

Mitsubishi is currently examining what level of capacitance it will use for its third generation version. For 30fF, the thick-film design will be used; for 40fF the single fin design will be used. For wiring technology, all of the companies are simplifying the embedding technique. Hitachi is adopting a three-layer metal construction. For exposure, Mitsubishi is developing a half-tone type phase shifting technique.

*Items marked with an asterisk are assumptions made by the editors.

Manufacturer		NEC	Toshiba	Hitachi	Fujitsu	Mitsubishi	Oki Electric	Matsushita Electronics	Samsung	Hyundai	Micron
Wire	Number of polycrystal Si layers	2	2	3*1	3	2	2	3	4	No response	2
	Number of polycide layers	2	1	1*1	1	2	2	1	No response	No response	1
	Number of metal layers	2	2	3	2	2	2	2	2	No response	2
	Contact embedding technique	Blanket W	None	Blanket W*1	Blanket W	Blanket W	Blanket W	Blanket W	Al Reflow	No response	W Plug
	First layer metal material	AlSiCu or W	Al	W	W	AlCu or W	W	AlSiCu	Al	No response	AlCu
	Planarization technique	SOG	Currently being examined	SOG + etchback	No response	SOG	TEOS	Etch-back	No response	No response	CMP
	Via-hole embedding technique	None	None	Blanket W	None	None	High temperature Al	Blanket W	No response	No response	None
	Second layer metal material	AlSiCu	Al	Al	Al	AlCu	Al	AlSiCu	Al	No response	AlCu
Light source for exposure		i-line	i-line	i-line	i-line	i-line	i-line	i-line	i-line	No response	i-line
Use of high resolution technology		No	No	No	No	Yes (half-tone)	No	Yes	No response	No response	No
Number of wells		2	3	2	3	2 to 3	2	2	2	No response	2

Note 2: The rough surface type achieves 1.5 to 2 times more storage node surface area without changing the construction. Oki Electric will adopt this method with the 16M second generation version. For the third generation version, a shield bit line construction will be adopted, while keeping the rough surface technique. Storage capacity for both the second and third generation versions will be 25fF. A problem associated with the rough surface technique is how to achieve consistent formation of the rough surface shape. Oki uses the ordinary furnace body to make the rough surface structure without changing the temperature and pressure conditions for polycrystal silicon film formation. In the past, it was necessary to control the inconsistency of process conditions, but Oki feels that this will not be a problem in mass production. Oki claims that a thick-film gauge will be sufficient to control particle size during processing. This is because an AFM observation showed a good correlation between the particle size and polycrystal Si thick-film in the rough surface. For its first generation version, Oki used two cell constructions—a simple stacked design for voice applications and a fin-type design for computers. The rough surface design will likely be used for all applications beginning with the second generation version. However, there is a possibility that the fin type design may also be used.

Process Continuity Concept Creates Division

The reason different structures came about in the stacked design is the different approaches taken by manufacturers regarding process continuity. One approach focuses on continuity between 16M and 64M generations, and the other approach focuses on continuity between the 4M and 16M generations.

Manufacturers which are focusing on continuity to the 64M generation have adopted the fin-type design. This approach is advantageous because the technology established for the 16M generation can also be used in the 64M generation by increasing the number of fins. Hitachi and Fujitsu have selected the fin type design. (See Figure 2.) Texas Instruments Inc. of the United States, which teamed up with Hitachi to develop the 64M chip, also plans to change from the trench design it used for the 16M second generation version to the fin design for the third generation version.[Note 3)]

Manufacturers focusing on continuity with the 4M generation have adopted the thick-film design. An extension of this technology can be used to obtain the cumulative capacity needed up to the first generation version of the 64M DRAM; and for successive generations, techniques which increase the surface area (such as roughening the storage node surface) and techniques which raise the dielectric constant of the capacitor insulating film can be used. NEC and Mitsubishi have chosen the thick-film design. Oki Electric will use the rough surface design for its 16M chip. Although the fin design was adopted for the first generation version, Oki will switch to the rough surface design for the second generation version.

Note 3: Samsung uses a single fin design for its third generation version. It also used this type in its second generation version. However, for the 64M DRAM, Samsung plans to use a cylindrical design. Two other Korean manufacturing companies plan to use the cylindrical design in their 64M products. The 64M DRAM is likely to become a joint development project for Korean manufacturing companies, reflecting the efforts achieved through technical cooperation among the three companies.

Number of Fins Increased for More Storage Capacity

Manufacturers which use the fin design are increasing the number of fins to obtain the storage capacity needed for each generation. (See Figure 3)

There are two advantages to the fin design: one is that a large surface area can be achieved, and the other is that the number of fins can be increased without requiring complex processes. This is why the necessary storage capacity can be achieved while using a small cell size. In fact, Fujitsu, which conceived the fin design and incorporated it into its products, has achieved the smallest cell sizes to date—2.86μm^2 for the second generation version, and 1.89μm^2 for the third generation version. Hitachi also has a cell size equivalent to other manufacturers, without using a shield bit line configuration which enlarges the projection area of the storage node.

Fujitsu will use the single fin design it adopted for its first generation version in its second generation version 16M DRAM. The third generation version will use basically the same processes used for the 64M chip, and a double-fin design will be adopted to obtain storage capacity of 30fF. Fujitsu has used the shield bit line construction since its first generation version.

Hitachi switched from the thick-film design it used for its first generation version to a 1.5 fin design for its second generation version. In this design, the lower layer of the fin is an ordinary storage node. For the third generation version, a 2.5 fin design will be used to achieve 30fF capacity with a cell size of about 2μm^2. The 2.5 fin technology is for the 64M DRAM which is now being jointly developed by Hitachi and Texas Instruments. Both companies are behind in shipping samples of the 64M DRAM, but they have recently focused efforts on increasing the level of chip completion by attaining processing proficiency. Although the first generation version of the 64M will not be carried to the mass production level, this technology will be linked to the third generation version of the 16M DRAM, according to Hitachi authorities. The shield bit line construction will not be adopted, but will become the subject of study for the second and later generations of the 64M DRAM.

A number of problems have been associated with the formation of the fins, but the companies which have adopted the fin design have resolved all of these problems by controlling fin thick-film and process conditions during formation. The problems are: (1) the first layer fin, which is formed at the same time as node contact embedding is performed, bends or breaks, and (2) although this is peculiar to plural fin designs, the lower layer fin, which is formed before the topmost layer fin at the same time that node contact embedding is performed, breaks off from its base.[Note 4)]

Fujitsu claims that this is "absolutely no problem at all," but has not described the corrective measures adopted.

With regard to problem (1) above, Fujitsu claims that it can be resolved by using a fin thick-film of 0.1-0.2μm, and controlling the process conditions such as the growth temperature for polycrystal silicon. When Fujitsu developed the fin design, this problem was directly confronted. Although initial efforts were directed toward a stress analysis, the growth conditions where bending did not occur were discovered through experimentation, and the stress analysis was discontinued.

There are two causes associated with problem (2) above. One is that the adhesion between the contact areas which support the fins and the fins themselves is insufficient. Another is that when the cleaning fluid dries, there is a force which bends the fins because of the surface tension of the cleaning fluid located between the fins. These problems can also be resolved by controlling the process conditions, such as the film growth temperature. In addition, there are methods which use cleaning fluid having minimal surface tension, and methods which

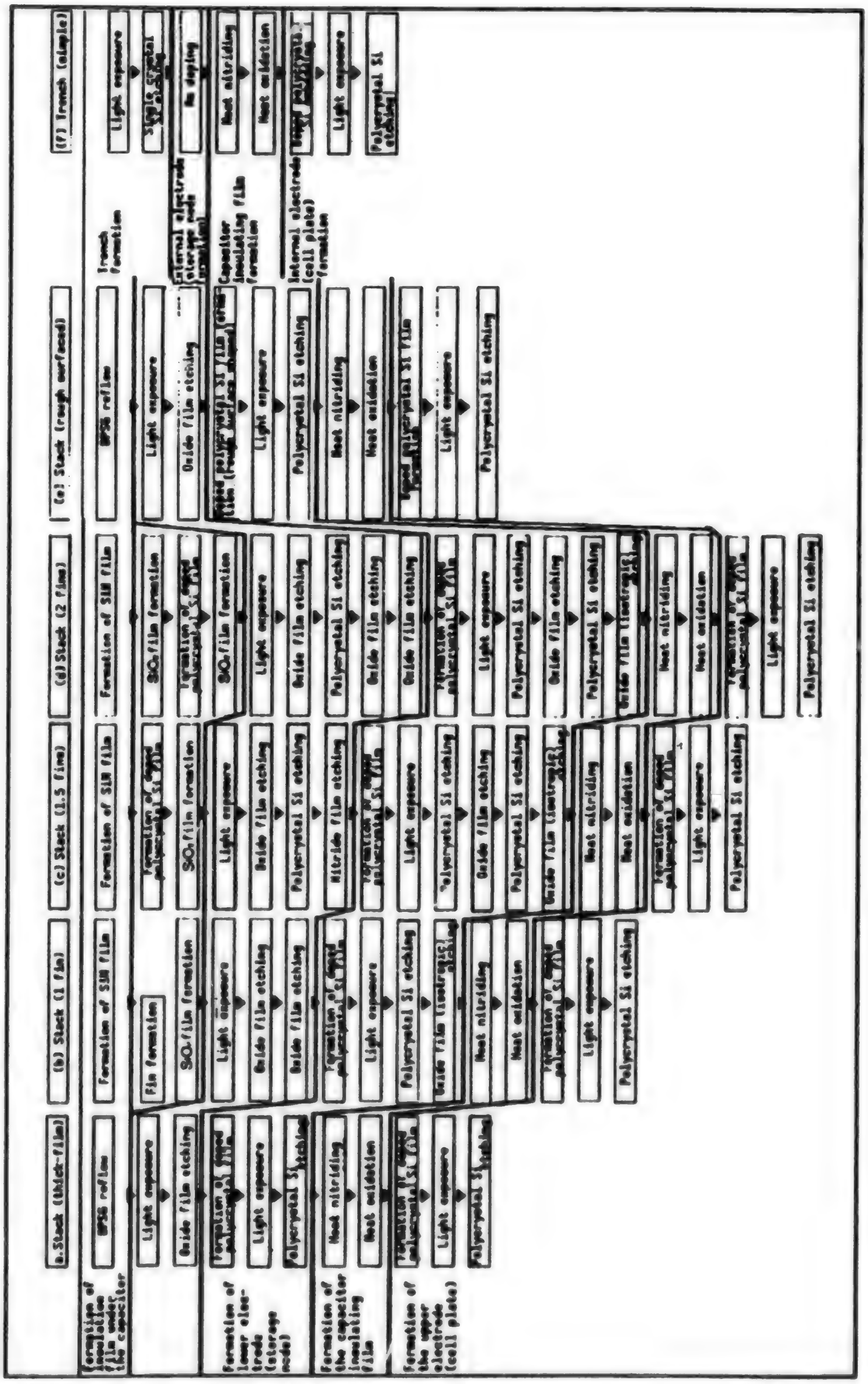

Figure 2. Process Flow for Various Cell Constructions. Examples of typical process flows. In some cases, polycrystal Si film and P doping is used instead of doped polycrystal Si film during formation of the electrodes. In these cases, in order to form a thick-film stack and to equally distribute the impurities, it is necessary to repeat the film formation and doping processes.

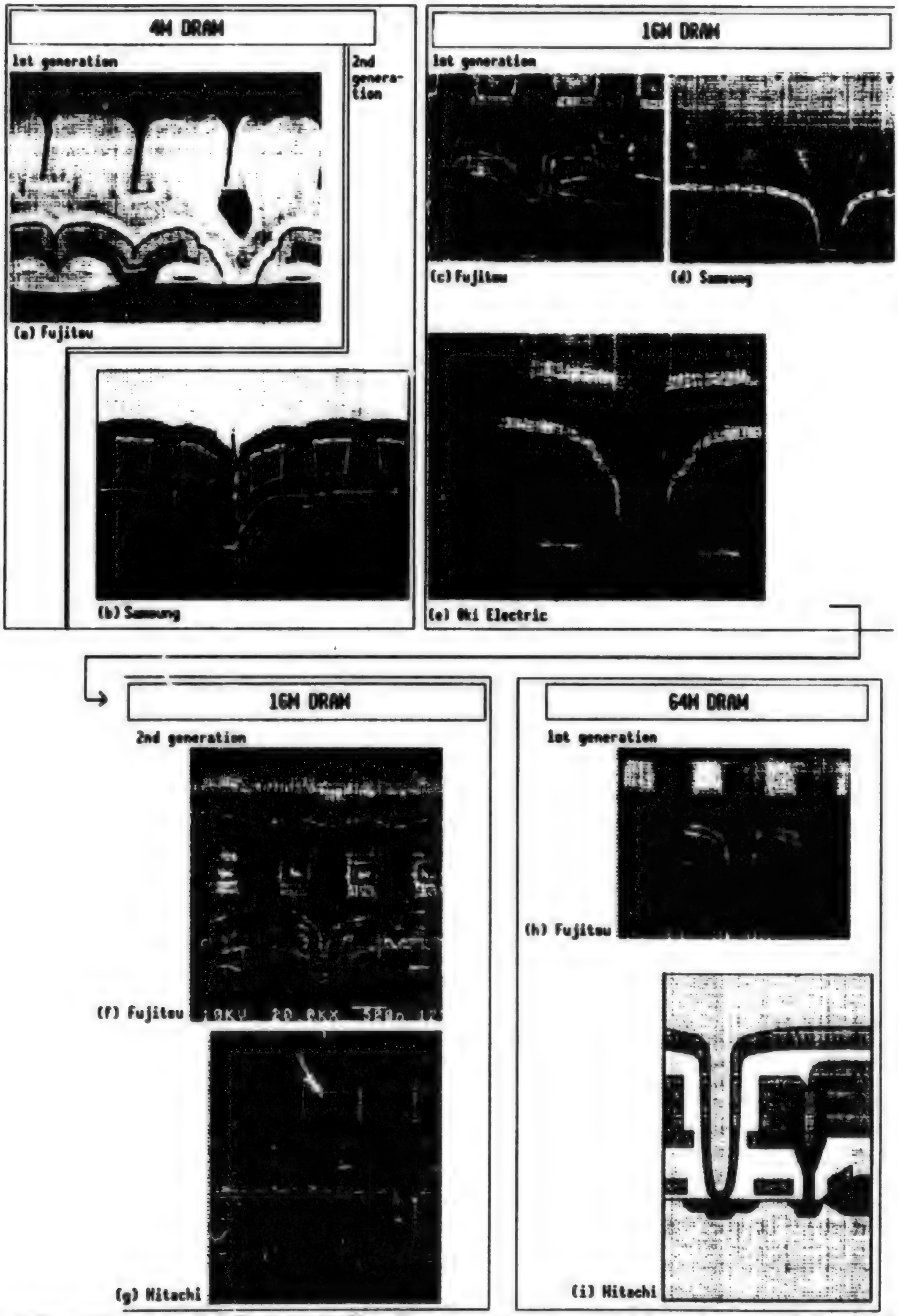

Figure 3. Transition of the Cell Structure in Fins. The storage capacity needed for each generation can be obtained by increasing the number of fins. (a) is a simple stack, (b) through (f) are single fin designs, (g) is a 1.5 fin, (h) is a double fin, and (i) is a 2.5 fin design.

adopt a dry cleaning process. However, Fujitsu feels that these are not needed at present. With regard to the precision of fin-to-contact alignment, insufficient adhesion caused by shifting can be avoided with the precision provided by current steppers.

Note 4: In addition, SiN is used in the interlayer insulating film which separates the capacitor electrode from the substrate, so SiN etching cannot be sufficiently accomplished, resulting in fin peeling and contact failure. This is resolved by developing an etching technique which has high selectivity during contact formation, and using this etching technique to sufficiently etch the SiN.

Higher Capacity Achieved by Increasing Film Thickness and Using Shield Construction

In order to assure the necessary cumulative capacity, NEC and Mitsubishi,[Note 5)] which have adopted the thick-film design, have thickened the storage node each successive generation, and have changed to a shield bit line construction which increases capacity. (See Figure 4)

NEC has used the same film thickness for its first and second generation storage nodes—0.4μm. However, it changed to a shield bit line construction for its second generation version. For its third generation version 85mm^2 chip, film thickness is 0.5μm; for the 70mm^2 chip, it is 0.6μm, and for the 64M first generation version, it is 0.8μm. Cumulative capacitance is 27fF for the second and third generation versions, and 25fF for the 64M generation. Mitsubishi is using a film thickness of 0.4μm or more for its second generation version, and also a shield bit line construction. For its third generation version, the capacitor insulating film is thinner and 30fF capacity is achieved.[Note 6)]

The thick-film design has the advantage that cell formation processes are an extension of the conventional single stack, but the step between the cell area and surrounding areas is larger. The countermeasure for this is to use a film thickness in the vicinity of 0.5μm.

NEC has used the shield bit line construction from its second generation version to suppress an increase in the storage node film thickness. This technique will also be used for the third generation version. To avoid step differences in 70mm^2 chips with 0.6μm film thickness, the array configuration will be changed. The pitch of one-layer metal wiring can be significantly lessened by using the divided word line method which is adopted in 64M DRAM with film thickness of 0.8μm. By doing so, the pattern can still be formed even if there is a step difference.[Note 7)]

Mitsubishi has improved the SOG method in order to lessen the step differences, by thickening the interlayer insulating film in peripheral areas, beginning with the second generation version. For contacts with a large aspect ratio, a combination of tapered etching and tungsten embedding techniques are used. The half-tone phase shifting method will be used for creating contact holes beginning with the third generation version.

Note 5: Matsushita Electronics will adopt 0.3-0.4m thick-film stack design for its first and second generation versions, and a shield bit line with 0.5-0.6m thick-film stack design in its third generation version and 64M DRAM. Both second and third generation versions will have a cumulative capacity of 25fF. To overcome the problem of step variation, flatness will be improved using a CVD technique with ECR high density plasma.

Note 6: In order to expand the design margin, Mitsubishi is also examining the possibility of 40fF cumulative capacity in its third generation version. In this case, the fin design could be adopted.

Note 7: In addition, with regard to thick-film growth methods, NEC is promoting the application of a formation method by doped polycrystal silicon which omits ion implantation. Also, since storage node contact holes are difficult to create due to subminiaturization, NEC is examining the use of self-regulating contacts in its 70mm^2 chips and in the 64M DRAM. For the second generation version of the 64M DRAM, the use of chemical mechanical polishing (CMP) is being examined.

Controlling Leakage Between Trenches

Toshiba, which is developing the second generation version 64M DRAM and the 256M DRAM jointly with IBM Corp. of the United States and Siemens AG of Germany, will shrink the size of trenches for the 16M with no further modification. (See Figure 5.) It has no plans to use the substrate cell plate design used in the 64M DRAM. Trench depth will be about 3μm and capacitance will be 30fF.

With regard to the simple trench design, the difficulty of controlling leakage between trenches due to subminiaturization has been pointed out in the past. It is certainly true that Toshiba's cell size is 3.62μm^2 for the second generation version and 2.8μm^2 for the third generation version, which is larger than any cell in the stacked type construction. However, Toshiba reports that this is because a margin has been added to the design rule presuming the use of conventional equipment. It claims that inter-trench leakage is not a problem up to the first generation version of the 64M DRAM. For applications in the second and later generation versions of the 64M DRAM, this will be changed to the substrate cell plate design. Since the process technology for the substrate cell plate construction has not yet been completely established, it cannot be used for application in shrink versions of the 16M. Advantages of the substrate cell plate construction are the control of inter-trench leakage and planarization.[Note 8]

Note 8: In 1994, Toshiba set a goal to increase productivity 250 percent by 1996. In order to achieve this, efforts are being directed toward simplifying the embedding process and decreasing the number of masks needed.

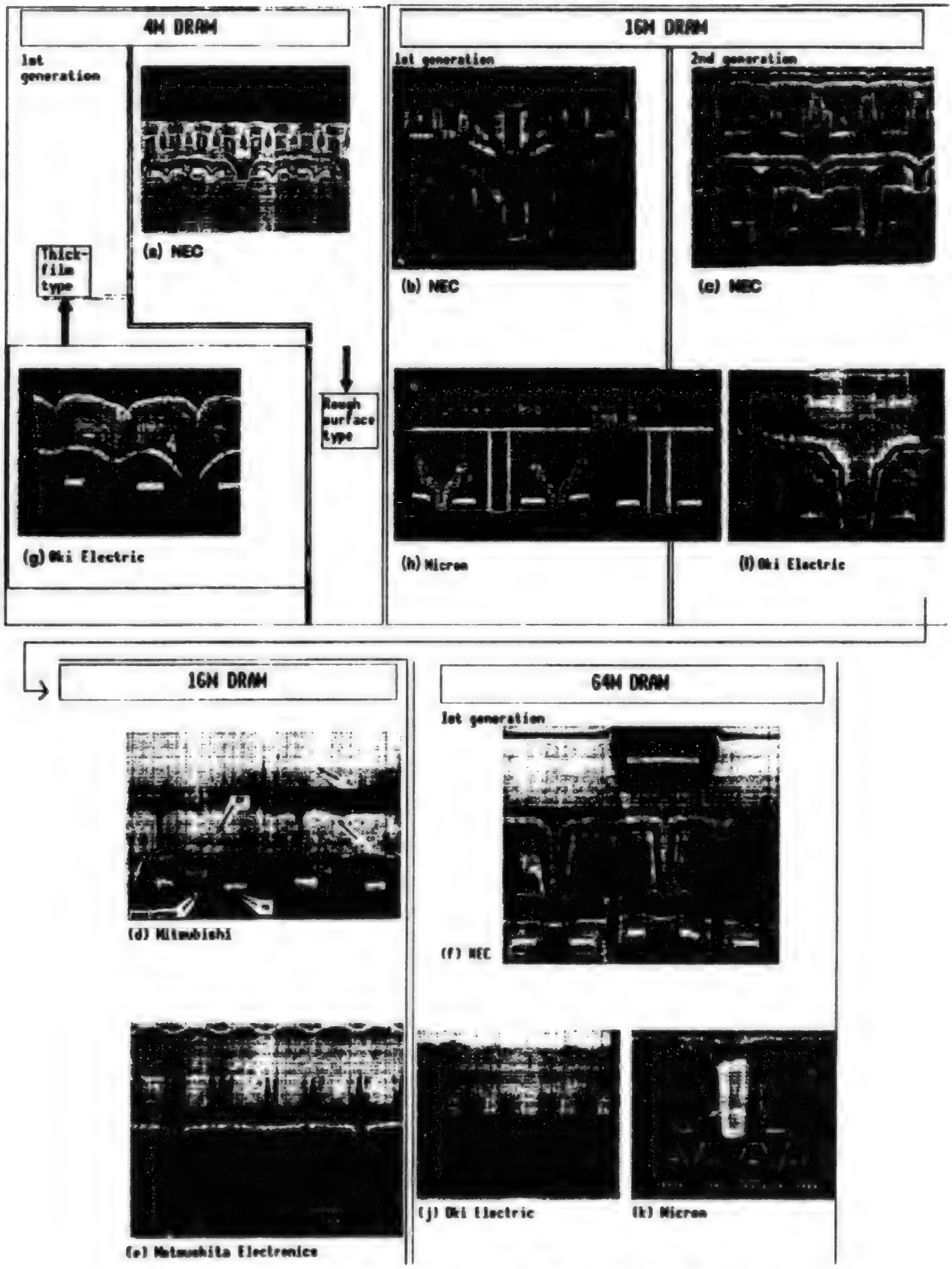

Figure 4. Transition of Cell Design Film Thickness and Surface Roughness.

(a) through (f) on the upper half of the illustration show the transition in thick-film stacked cell design. (a) is a simple stack, (b) is a thick-film stack without a shield bit line, and (c) through (f) are thick-film stacks using the shield bit line design. The film thickness increases with each successive generation. On the other hand, (g) through (k) on the lower half of the illustration show the changes in cell structure with rough surface. (g) and (h) are simple stacks, and (i) through (k) are rough surface stacks. (k) shows a combination with cylindrical design. Of these designs, (a) was featured in the December 1990 issue of this magazine (p. 83), (g) was discussed in the November 1989 issue (p. 133), and (i) and (k) were included in the November 1993 issue (p. 30).

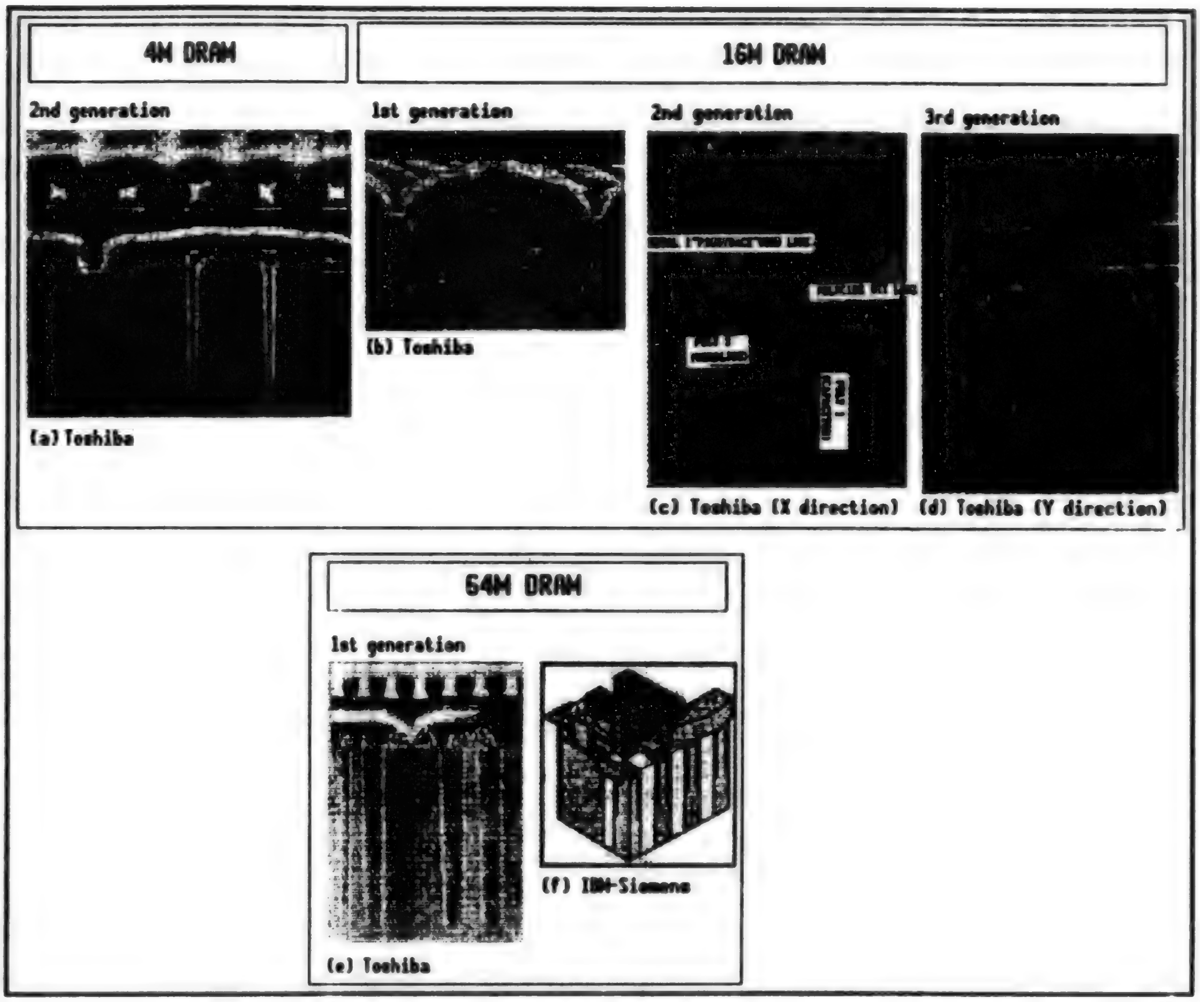

Figure 5. Transition of Trench Design.

(a) through (d) are single trenches. (e) and (f) are the substrate cell plate type. (a) was described in the June 1990 issue of this magazine (p. 68), (b) was featured in the December 1990 issue (p. 83), (e) was included in the November 1993 issue (p. 30), and (f) was contained in the November 1993 issue (p. 39).

Simplification Targeted With Use of Tungsten Wire

To simplify processing, the combined use of blanket tungsten and etchback methods for embedding contact and via-holes, and the use of selective W should be discontinued.

Companies which are using the stacked design are forming the first layer of wiring using tungsten at the same time that contact holes are created, thereby eliminating the need for etchback. Hitachi decided to use this method beginning with its second generation version; Fujitsu and Oki will use it beginning with their third generation versions. NEC and Mitsubishi are also headed in the same direction, but they are also examining the parallel use of the conventional etchback method and aluminum wire. Toshiba, which is adopting a trench configuration with superior flatness, does not use embedding techniques, and embeds aluminum wire as it is without modification.

For via-holes, most of the manufacturing companies are embedding aluminum wire without further processing. Toshiba has discontinued the use of selective tungsten, and embeds aluminum using tapered etchback. Hitachi, which will use three-layered wiring beginning with its third generation version, will use tungsten for via-hole embedding between the first and second layers, and aluminum for the second layer of wiring.

Part 2. Business Strategies

Sharp Increase in Production, Companies Race to Expand Production Systems

From now and into 1995, major DRAM manufacturing companies, both domestic and foreign, will begin to sharply increase production of the 16M DRAM. They are determined to expand the capabilities of their production facilities and increase the number of product lines. The production amount of six Japanese companies and three Korean companies combined will increase about 5 million chips per month each quarter, and by the fourth quarter of 1995, will reach 34 million chips per month. The main product function will initially be a new operating mode which facilitates the use of a conventional high-speed page mode, and then the quantities of synchronous DRAMs will increase. On the user's side, the main memory of each personal computer will exceed 10M bytes, thereby stimulating demand for the 16M DRAM. Although there is concern that the supply of production equipment to support the increased production of the DRAM will be delayed, this does not seem to be a major problem.

The 16M DRAM is finally becoming serious business. DRAM manufacturers in Japan and abroad are sharply increasing production amounts and will continue to do so into 1995. According to a survey done by the editors, the combined production amount for six Japanese companies and three Korean companies will grow 5 million chips per month each quarter, and is expected to reach 34 million chips per month by the fourth quarter of 1995. (See Figure 1.) Companies are investing in the construction of new production lines, and some of the largest producers will reach the 6.5 million chips per month level by the end of 1995. As for the types of DRAMs being produced, models will include chips which provide the high-speed function which has been available up to the 4M generation, but the main model will provide an operational mode that is easier to use and is even faster. The proportion of synchronous DRAMs will also gradually rise.

Applications of the 16M DRAM are expanding to include personal computers. With the spread of Windows 3.1, the main memory capacity of each PC will increase to 10M bytes. In addition, the bit unit price will soon match that of the 4M DRAM, thereby stimulating demand for the 16M DRAM in system applications. Storage capacity will increase even further when a new operating system is introduced at the end of 1994.

Although the supply of production equipment for the increased DRAM production is a bit behind schedule, it appears that this will not be a major problem.

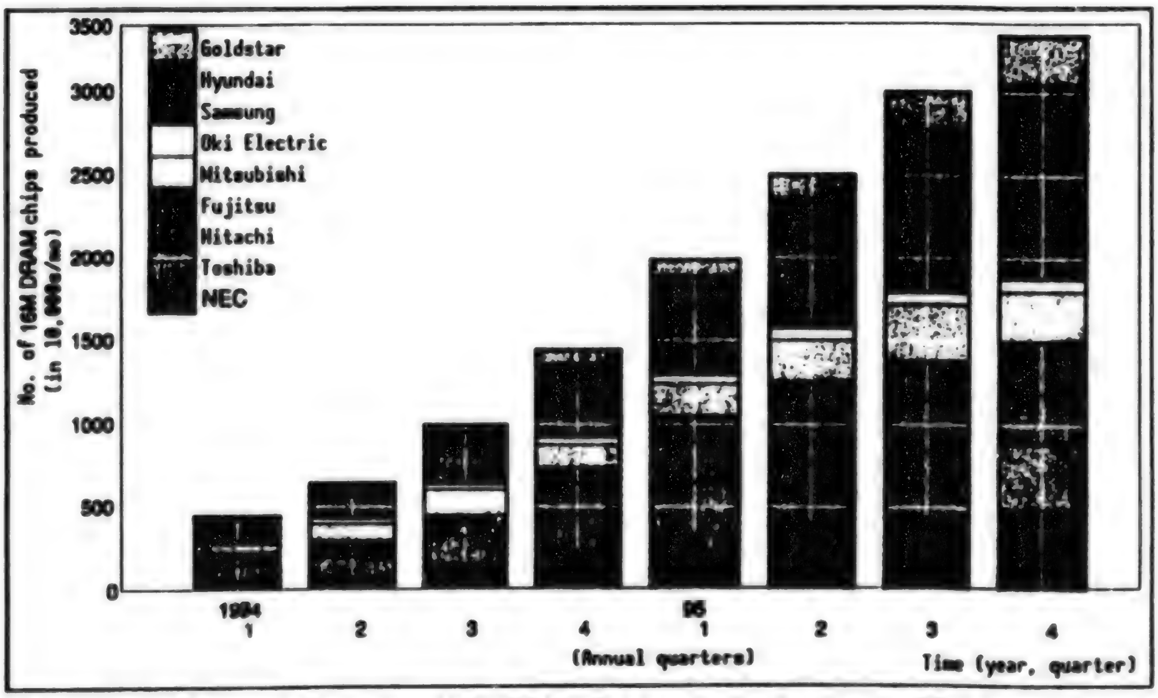

Figure 1. Sudden Increase in Production of 16M DRAM. Total production for six major DRAM manufacturers in Japan and three in Korea. The total number of chips will increase from 85 million chips per year in 1994 to about 300 million chips in 1995, with a growth of about 3.5 fold per year. Since it is clear that there will be no growth in 4M DRAM production, the bit growth rate taking into account the 4M is about 1.6 fold. (Data was compiled through an editor's survey.)

DRAM Manufacturers Race to Increase Production

The production amounts for the various major DRAM manufacturing companies at the end of 1994 will increase to 6.4 million chips per month for large producers, and 3 million chips per month for most of the others. (See Figures 2 and 3.) These amounts represent three to four times the amount currently being produced.

The companies which will boost production to 5 million chips/month or higher are Samsung Electronics Co. Ltd., Hyundai Electronics Industries Co. Ltd., and NEC. All three companies are setting up equipment in newly constructed production lines.

Samsung plans to be producing 6.5 million chips per month by the end of 1995. In addition to full operation of its already existing No. 5 line, Samsung will start up operation of its No. 6 line at the end of 1994, and have it in full swing at the end of 1995. During the same period of time, Hyundai will be producing 5 million chips per month. Hyundai's already existing E2 line will be in full operation by the end of 1994, and its new E3 line will start up in the beginning of 1995. Hyundai also plans to start up an additional line sometime during 1995. (Refer to separate article at end.) NEC will produce 5 million chips per month at the end of 1995. In addition to NEC's new production line in Kyushu, production will be boosted at its Roseville factory (in California, U.S.).

Toshiba and Hitachi plan to produce 4 million chips per month at the end of 1995. Toshiba will start up its "Step 1 Module 2" line in Yokkaichi during the third quarter of 1994, and bring it up to full production by mid-1995. Tohoku Semiconductor's "Step 3," a production line established together with Motorola of the United States, will also start up in Spring 1995, and half of the production amount will belong to Toshiba. Hitachi will use its new production line in Naha as well as its 0.5μm production line in Germany.

Fujitsu, Mitsubishi Electric, and Goldstar Electronics Co. Ltd. of Korea are planning a production scale of 3 million chips per month. Fujitsu, which had temporarily postponed investment for the DRAM, announced its intentions for the 16M in July 1994. Fujitsu will invest ¥50 billion during the three-year period from 1994 through 1996. At its Iwate Plant, half of the remaining open space will be used at its No. 4 building. Mitsubishi will start up the "2B" line in its Seijo Factory A wing, during the third quarter of 1994, and will boost production capability there throughout the next 12 months. Goldstar will bring its already existing "C2" line up to full operation by the beginning of 1995, and plans to start up a new line at that same time.

Although production will be only 1.2 million chips per month, Oki Electric Industrial Co. has set up a plan to increase production at its own factory as well as at the plant of an associated company which is supplying technology. Operations will start up at the associated company, Mosel Vitelic Inc. of Taiwan, and production for Oki will start at the beginning of 1995. At the end of 1995, operation will begin at Oki's "S2" factory in Miyagi.

Mid-range Increase Also a Possibility

Although the production plans up to the end of 1995 are definite, plans for further growth of the 16M beyond that point are not so clear. In preparation for the increased production, it is necessary to take action at least by the beginning of 1995, according to Mitsubishi. It takes one to one and a half years from the time construction begins on the clean room until the first wafer is produced, and if the building itself must be constructed, it takes about two years. Although the Japanese companies just announced their FY94 investment plans in May, there is already the possibility that investment amounts may be increased, according to NEC Managing Director H. Sasaki.

At present, the only plans involving new construction for 1996 and later include the "S2" line of Oki Electric, and Nanya Plastics Corp. of Taiwan, which supplies technology to Oki. Nanya has an aggressive plan, and is investing ¥70 to 80 billion for startup operations in 1997, with plans to invest the same amount again one year after operations have started.

Even after increased production systems are in place at the end of 1995, the following companies will still have open space to install more equipment: NEC Kyushu's "8th Diffusion Line," first floor; Hitachi's "N2" line in Naha, first floor, and its Germany plant; Mitsubishi's Seijo Plant, Wing A, Kumamoto Plant, first floor, and its Germany Plant; and Fujitsu's plant in England. There are no plans at present to start construction on clean rooms at these locations. Toshiba has no vacant space, and will have to construct a new factory.

EDO (Extended Data Out) First, Then Synchronous

All of the companies will shrink the size of the chip, and manufacture a standard product which provides a new operational mode that improves usability. This will challenge the market for the 16M DRAM.[Note 1] According to Hitachi, a chip which incorporates a new mode that makes it easier to use the conventional high-speed page mode will be the first to be mass produced. The new mode is called EDO (extended data out). Then, a gradual shift will be made toward the synchronous DRAM. (See Figure 4 and Table 1 [not reproduced].)

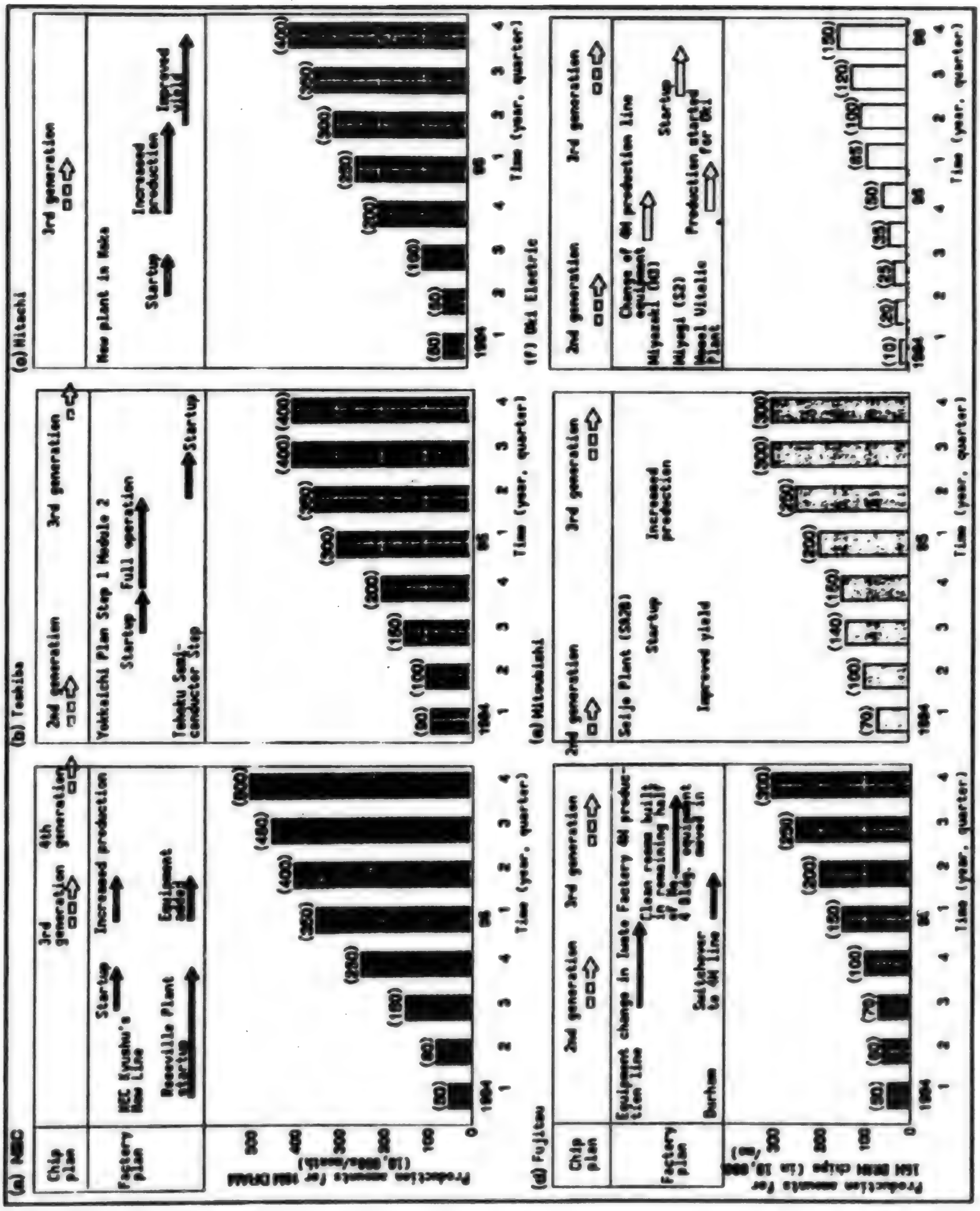
(a) NEC
(b) Toshiba
(c) Hitachi
(d) Fujitsu
(e) Mitsubishi
(f) Oki Electric
Chip plan
Factory plan
Time (year, quarter)

Figure 2. Plans for Increased DRAM Production by Six Japanese Companies. In all cases, data is based on production plans announced publicly. For second quarter 1995 and later, data was estimated by the editors.

(a) During the first quarter of 1995, NEC plans to ship half of its production amount from its Roseville Plant. The NEC Kyushu production line will initially process 8,000 wafers per month. This will reach 15,000 wafers/month after the increase takes effect. After adding equipment at the Roseville Plant, production will be 20,000 wafers/month for the 16M DRAM. There may also be a mid-range increase to accommodate production in 1996 and later. At the time of the mid-range increase, overseas factories may take priority depending on the valuation of the yen at that time. (b) Toshiba's plan. Tohoku Semiconductor's Step 3 will be in full operation before the end of 1995. Half of the production amount will belong to Toshiba and half will belong to Motorola (USA). (c) Hitachi's plan. The Naka Plant will initially process 5,000 wafers/month. The 0.5μm production line in Germany will shift from the 4M to the 16M DRAM. (d) Fujitsu's plan. Fujitsu announced additional investment in its Iwate Plant in July 1994, and will invest ¥ 50 billion over a three year period. ¥ 9 billion will be used for constructing clean rooms in 1994. In the first half of 1995, equipment to produce 10,000 wafers per month will be installed, and in 1996 full operation will be underway at 15,000 wafers per month. As a result, production of the 16M at the end of 1996 will be 5 million chips per month. (e) Mitsubishi's plan. Vacant space is available at the Kumamoto Factory, first floor, and at the factory in Germany. (f) Oki Electric's plan. This includes the production by the Taiwan manufacturing company which supplies technology to Oki. In addition to the above, Matsushita Electric Industrial Co. plans to produce 1 million chips per month during the second quarter of 1995, with the support of its Tonami and Uozu Plants.50ns, is about 35ns in high-speed page mode, and 20ns in EDO mode. A 20ns cycle time can be used at 50MHz, and the valid period for data can be lengthened by using this as the 35ns cycle. Since the timing margin on the printed circuit board can be cut back, this simplifies the board design. This is why the chip will likely be used for main memories in personal computers. According to Hitachi, all PC manufacturers are currently unanimously in favor of adopting the EDO chip.

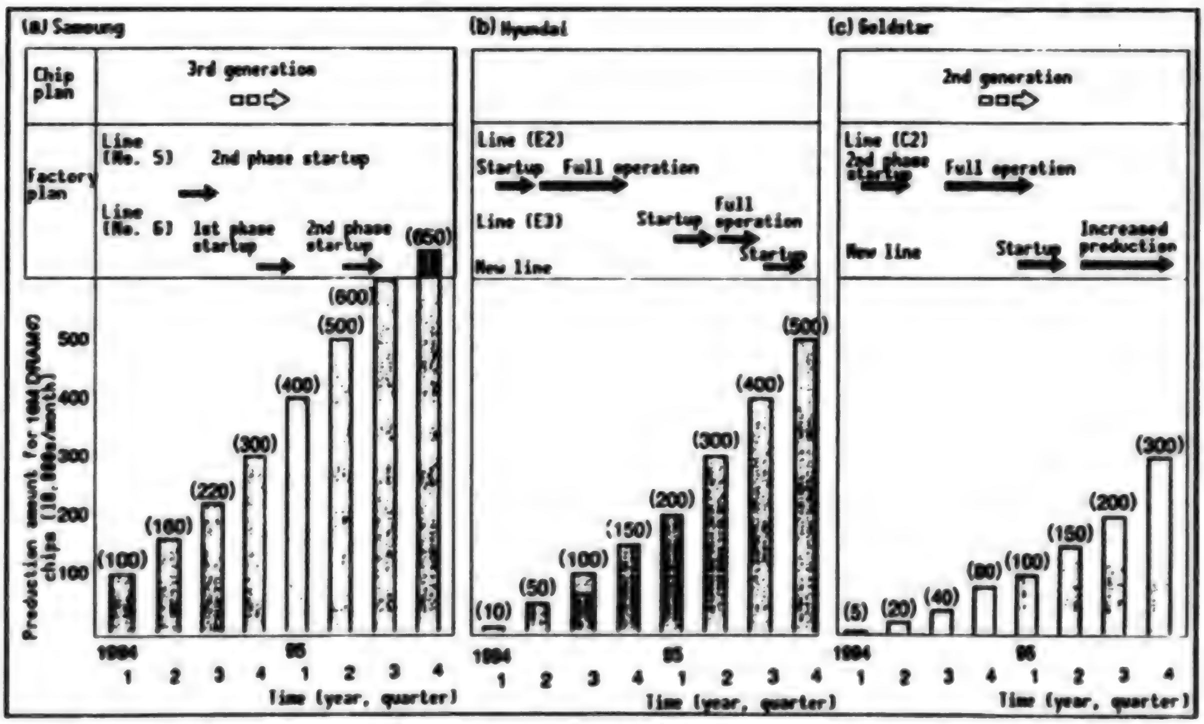

Figure 3. Increased Production Plans for Three Korean DRAM Manufacturing Companies. Production plans for each Korean company are shown. The formally announced production plans have been inspected by the editors. Some estimates are also included.

(a) Samsung's production plan. (b) Hyundai Electronic's production plan. (c) Goldstar Electric's production plan.

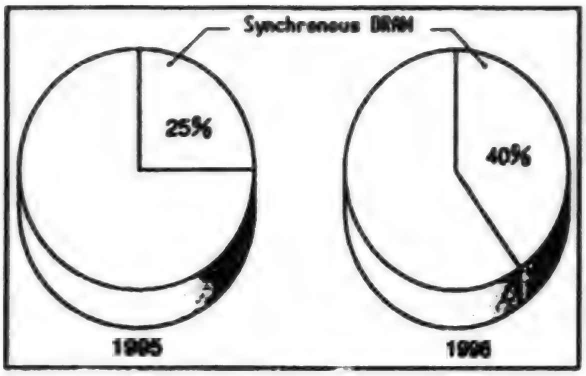

Figure 4. Increase of Synchronous DRAM Proportion (according to NEC)

EDO is a function which makes it easy to use the conventional high-speed page mode even at maximum operational frequency. Compared to high-speed page in which data is valid only during the period when the CAS [overline] signal is present, in the EDO mode, data is valid from the time when the CAS [overline] signal enters until the end of the next CAS [overline] signal. The cycle time for products having an address access of

On the other hand, there has been an increasing call for use of the synchronous DRAM in workstations, according to NEC. This is because the premium is 10 percent lower than standard products. When a 30-40 percent premium was added to samples shipped a year ago, the call for the synchronous DRAM was weak. Some companies have reported that they would switch to the synchronous DRAM if 5 percent of the users requested it. It has become clear that the synchronous DRAM will spread in the future, together with lower priced workstations.[Note 2)]

However, before the synchronous DRAM will be widely used with personal computers, a memory controller which corresponds to the synchronous DRAM must be developed. Taiwanese manufacturing companies, which produce most of the printed circuit boards, will use controllers which are on the market in order to lower the price of the mounted circuit boards as much as possible. There are few companies which will design their own controllers independently (unlike workstation applications). For this reason, the shipment of controllers greatly affects demand for the synchronous DRAM. OPTi, Inc., a major U.S. manufacturer of controllers, is planning to ship chip sets for synchronous DRAM versions in 1995; if several other manufacturers follow suit and the price drops, the synchronous DRAM could become widespread.

Note 1: In addition to the choice between EDO and synchronous, companies are divided on word configuration and power voltage. The word configuration may be x9 or x8 for parity, because fewer chips which use parity are being used in lower-price personal computers. Hitachi, Mitsubishi, and Oki will not use parity. Instead, the chips will use a 1Mx2 or 2Mx2 word configuration. Toshiba has begun shipping a chip that has a x9, x18 word configuration, because they feel that it is more cost effective to use a single chip approach. Most of the chips will conform to a voltage of 5V or 3.3V, but Oki's third generation version will only use 3.3V. NEC is currently examining the question of voltage.

Note 2: Most synchronous DRAMs conform to 100MHz, but Mitsubishi Electric has recently questioned this practice. This is because a 100MHz memory system can be built by interleaving 50MHz EDO chips. It has been pointed out that in the synchronous version, a chip faster than 100MHz is needed; one on the order of 150-200MHz will be required. Mitsubishi feels that the market will expand for a chip at this frequency even if the chip is priced slightly higher than the EDO chip.

Unit Bit Price Approaches Crosspoint

In terms of systems and applications, an environment which uses large quantities of DRAMs has already been established. The main application is, of course, main memories in personal computers.[Note 3)] The following forces are driving the demand for DRAMs: (1) the bit unit price of the 16M is just about to cross the bit unit price of the 4M DRAM (see Figure 5); and (2) due to the introduction of new operation systems and new types of MPUs, the capacity of main memories in personal computers is increasing even further. These factors back up the estimates of DRAM makers regarding the growth of bit demand. That is, growth is estimated to increase 1.5-1.7 fold in 1994 relative to the previous year, and growth will increase 1.4-1.6 fold during the 1995-1996 period.

(1) Compared to the x1, x4 4M DRAM, the bit unit price for the 16M DRAM will cross that of the 16M chips which use the x1, x4 word configuration sometime before the end of 1994. There is also a strong possibility that the bit unit price for chips with high bit configuration such as x16, will do the same thing in mid-1995. In this way, the environment for application in personal computers will spread suddenly. At present, with the use of "Windows 3.1," the average capacity per personal computer has increased to 10M bytes. There is an active movement among PC manufacturers to install 8M bytes of memory on units. The crossing of the bit unit price will accelerate this movement even further.

(2) The introduction of advanced operating systems and high performance MPUs in 1995 will increase the main memory capacity in PCs even further.

With regard to operating systems, the next-generation version "Chicago" could be introduced as early as December 1994. Although 4M bytes is sufficient for simple operation, according to Microsoft Corp. of the United States, "16M bytes is needed for optimum performance, and 32M bytes will be needed in two or three years when advanced application software is introduced."

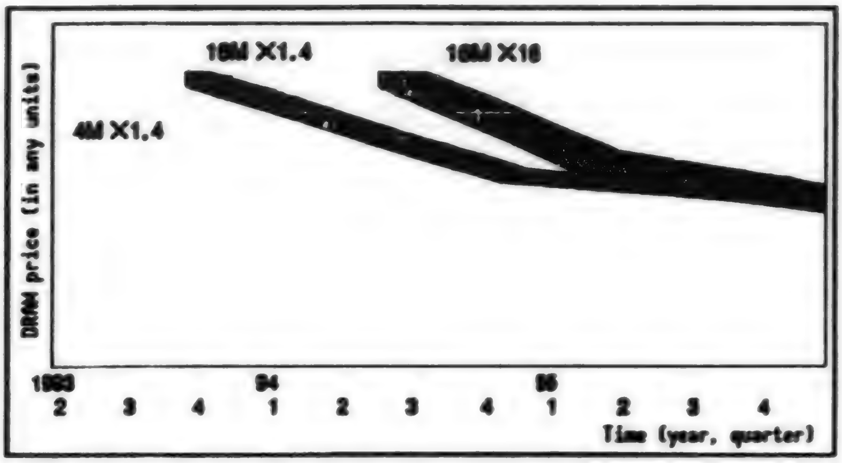

Figure 5. Bit Crosspoint Just Ahead. Sometime between August and December, the bit unit price for the x1, x4 configuration in the 16M DRAM will cross that of the 4M DRAM. There is a strong possibility that in mid-1995, the bit unit price for the x16 configuration may also do the same. Products which use the x8 configuration are in a state of flux. This depends on what type of pricing strategy Samsung and Mitsubishi, which have incorporated the x1, x4 and x8 configurations into one chip, choose to take. Many feel that the price will not drop much after the bit unit price crosses. Data collected from news sources.

With regard to MPUs, Intel Corp. of the United States will expand production of its "Pentium" and "Intel DX4" in 1995. Intel plans to almost triple production of the Pentium to 20 million chips per year. Personal computers containing the Pentium will require at least 8M bytes and preferably 16M bytes for optimum performance, according to Dave House, Senior VP, Corporate Strategy, Intel.

This trend was displayed realistically at the Windows World Expo/Tokyo '94, a software exhibition held in June for equipment associated with Windows software. Based on past trends, the models displayed at this exhibit normally find their way into the office environment within one year, according to spokesmen from Microsoft and Japan IBM. Since most of the personal computers displayed at the exhibit contained 16M byte memories, there is a possibility that the average storage capacity of PCs may reach 16M bytes as early as 1995.

Note 3: This discussion focuses chiefly on the main memory for the following reasons. It has been pointed out that chip quantities for imaging applications will increase sharply in the future. However, most of the DRAM manufacturers are of the opinion that the ratio of main memory applications to imaging applications will remain 8:1, as it has in the past (according to Toshiba). This is because although imaging applications are shifting from 1M to 2M bytes, the main memory of models which contain the 2M byte chips will be 16M bytes.

Supply of Production Equipment Not Assured

Something which may put a damper on the strong drive which Japanese DRAM makers have to increase production of the 16M, is the capability of production equipment manufacturers. Delivery of some equipment is already behind schedule, and concern by DRAM makers is mounting.

According to Tokyo Electron and Nikon, the demand will somehow be met. Tokyo Electron reports that by working overtime and making other arrangements to raise the rate of operation 100 percent or higher, equipment can be supplied with a one month delay at most. However, the supply capacity is very near its limit at present, and Tokyo Electron reports that the addition of even one more large investment would result in the inability to keep up.

DRAM manufacturers are most concerned about the status of steppers. Since stepper makers do not begin to make the lens until an order has been received, it takes nine months until delivery can be made. Therefore, stepper manufacturers are putting out feelers for the equipment which will be used for 16M DRAM production in 1995. From the production plans of various DRAM manufacturers into 1995, an estimated 250 steppers will be needed. After other steppers for production lines are added, the total comes to 500-600. As for assuring the lens materials for this number of steppers, the combined production capabilities of Nikon and Canon appears to be sufficient as long as investment in glass materials is increased.

Tremendous Investment by Korea; Could Possibly Exceed That of Japan for DRAM

Korea's investment in equipment for LSI production in 1994 will be overall, about ¥320 billion (at an exchange rate of ¥0.129 per won), as shown in Figure A. This figure was determined by a survey made by Korea's Industrial Research Institute and Department of Commerce and Resources. Since most of this investment is regarded to be used for the DRAM, the amount of

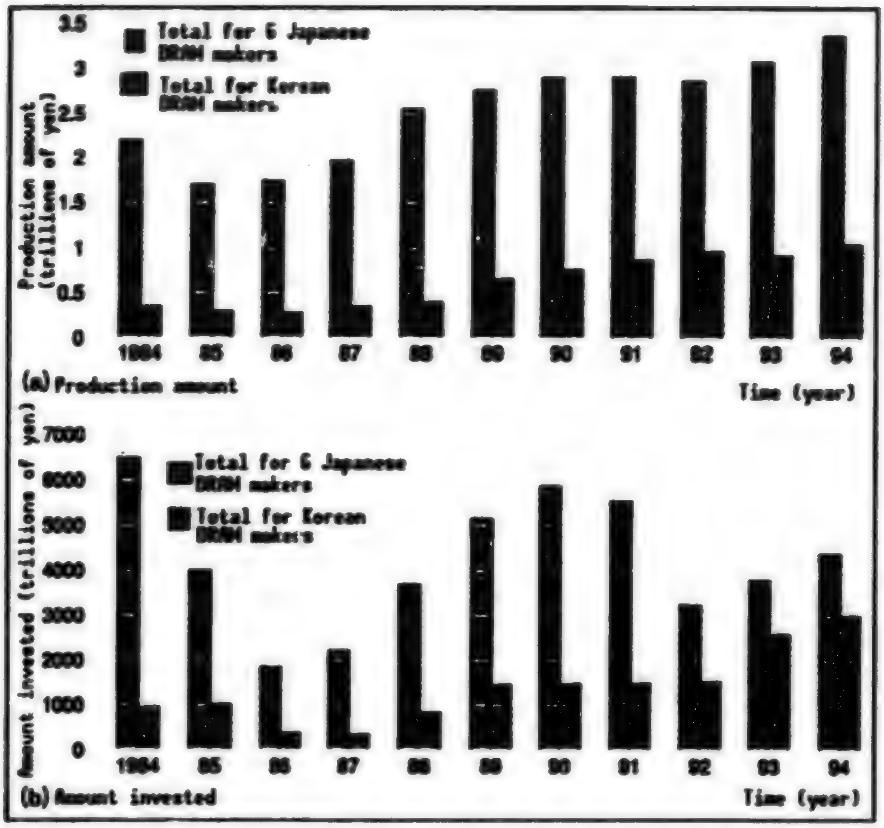

Figure A. Correlation Between Production and Equipment Investment Amount. (a) is the production figure, (b) is the amount invested in equipment. Data for Korea is per the Industrial Research Institute and survey by the Trade Resources Department

investment made by Korean makers for the DRAM will "at least equal that made by Japanese manufacturing companies," according to Japanese DRAM spokesmen.

Most of Korea's investment will be made by its three major LSI companies for the 16M DRAM. On the other hand, the investment made for equipment by six major Japanese DRAM makers for FY94, as announced at the closing of FY93, is ¥461 billion. Even with the high estimate (made by Japanese DRAM companies) that the proportion invested in the DRAM is 70 percent, this indicates that the amounts invested by both Korea and Japan are about equal. Since in reality the proportion is lower, there is even a chance that Korea's investment is greater, according to Hitachi, Ltd.

The problem for Japanese manufacturing companies is that there is an increasing possibility that the production base for the 16M and later generation DRAMs may move to Korea. This possibility cannot be denied, in view of the fact that "there is a strong correlation between the investment amount and the production amount one to two years later, based on prior experiences" according to U.S. DRAM makers. Although it is good that Japanese manufacturing companies are focusing on logic products which have high added value, there is also an impending fear that losing the advantage over the DRAM would result in a "total loss," according to NEC.

Latest Accomplishment of JT-60U Deuterium Experiment and Radiation Safety

95FE0226A Tokyo GENSHIRYOKU KOGYO in Japanese Sep 94 pp 36-46

[Article by N. Miya, Japan Atomic Energy Research Institute, Core Plasma Research Division]

[FBIS Translated Text]

1. Introduction

Since being remodeled between 1989 and 1991 in order to increase the level of current, the JT-60 (JT-60U) has been used to conduct experiments in two major research projects to improve plasma confinement capability and to achieve a steady state operation. The purpose of the JT-60U facility is to help solve the main physical problems concerned with the ITER[1] (international thermonuclear experimental reactor) through R&D to improve plasma confinement, to achieve a steady state tokamak operation, and to carry out advanced research essential to designing future power reactors. In recent experiments involving the JT-60U,[2] we at the Japan Atomic Energy Research Institute have achieved results in these two areas that far surpass anything that has been achieved so far.

Besides this research, we are also involved in an important research project on the effects of radiation, and another on the safe experimental operation of the JT-60U. With deuterium operations, we are involved in a new research project to understand the effects that neutrons produced by fusion reactions and secondary gamma rays have on shielding, and to understand tritium retention within the primary walls of the vacuum confinement vessel activated and produced by the JT-60U.

In this paper, we will describe the main results obtained in research on plasma confinement and steady state operations of the JT-60U, and discuss the results obtained so far assessing radiation safety with deuterium experiments.

2. Facility Profiled

In Figures 1 and 2, we show a general view of the JT-60U facility[3] and the inside of the vacuum confinement vessel. In Table 1 and Figure 3, respectively, we list the main specifications and show the longitudinal structure of the facility. The facility is 3.4 meters across and 15 meters tall and is housed inside a main chamber surrounded by a 2-meter thick concrete shielding wall. When we started using deuterium gas, the shielding properties of the building were reinforced including sealing the portals in the main housing chamber in order to provide shielding against the radiation of neutrons generated by electrical discharges.

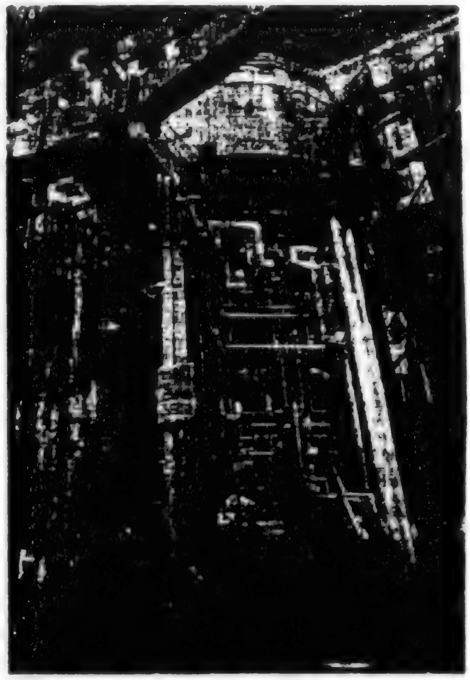

Figure 1. General View of JT-60U Facility

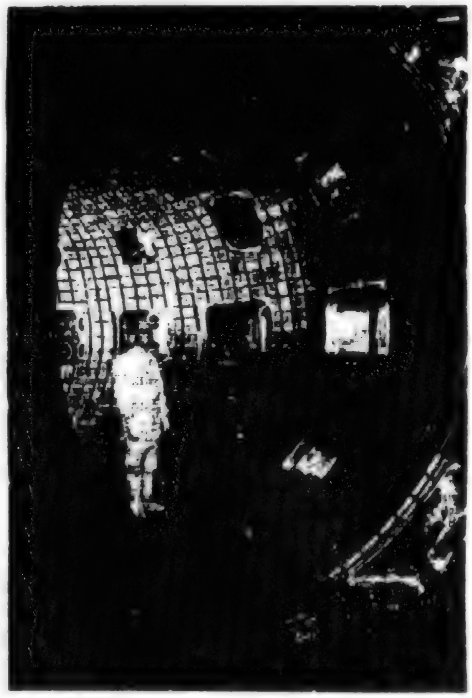

Figure 2. Inside of Vacuum Confinement Vessel

Table 1. Main Specifications of JT-60U Facility

Item	Design specifications
Plasma current (MA)	0.26-5
Diverters	6
Primary plasma radius (m)	3.4
Secondary plasma radius (m)	1.1 (horizontal)/1.5 (vertical)
Non-circularity degree	1.4-1.8
Toroidal magnetic field (T)	4.2 (3.4m primary plasma radius)
Plasma discharge time (s)	15
Injected neutral particle heat output (MW)	40
High-frequency heat output (MW)	ICRF 5, LHRF 10

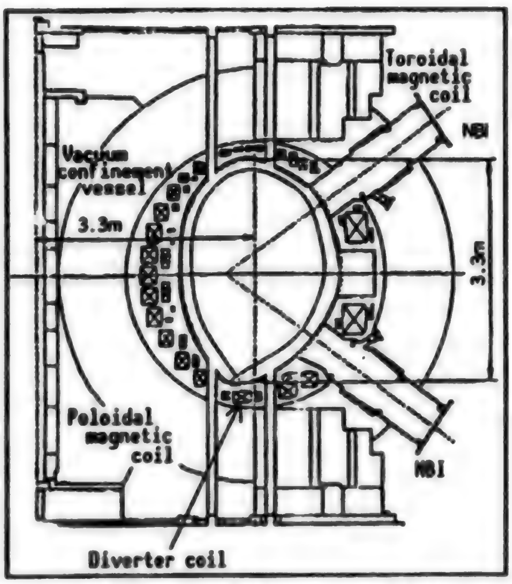

Figure 3. Longitudinal Structure of JT-60U

The vacuum confinement vessel is 3.3 meters tall and 2.4 meters wide and has an elliptical shape and more than 50 large portals located obliquely along the inside surface of the vessel that are openings used to heat plasma and take measurements. The entire inside of the vacuum confinement vessel has been layered with 10,000 graphite tiles that make up the primary shielding wall so that it can withstand the confinement of high-temperature plasma and to cut down the level of impurities in the plasma.

The discharge experiments conducted so far have taken place in toroidal magnetic fields between 0.5 T and 4.0 T and with plasma currents between 0.26 MA and 5.0 MA, but the JT-60U, being a large-scale tokamak facility with a diverter configuration, has the capability of conducting experiments in the 4T range which is an extremely intense magnetic field. This diverter configuration is a magnetic configuration that uses diverter coils installed along the bottom of the vacuum confinement vessel to form magnetic lines of force along the peripheral region of the plasma so that charged particles flowing along the outside of the main plasma do not come into direct contact with the inner surface of the vacuum confinement vessel. This diverter configuration enables charged particles to be led outside next to the magnetic lines of force and reduces the amount of impurities inside the plasma.

In Figure 4, we illustrate the principle behind a tokamak device. The toroidal magnetic coils produce a strong confinement field in a direction parallel with the doughnut-shaped plasma. The magnetic field induced by the current flowing within the plasma and the combination of toroidal magnetic fields enables helical magnetic lines of force to enclose the plasma. By confinement of the magnetic lines of force, the plasma is confined inside the vacuum confinement vessel maintained at a super high vacuum state. The location and longitudinal shape of the plasma are further controlled by poloidal magnetic coils.

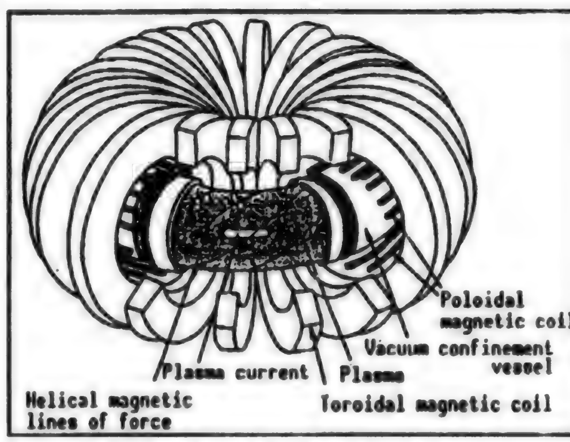

Figure 4. Principle of Tokamak Device

In trying to achieve a highly economical and efficient thermonuclear reactor, the indicator used is the beta value of plasma. The beta value includes the toroidal beta value β_p and normalized beta value β_N. The toroidal beta value indicates the plasma pressure relative to the pressure of the poloidal magnetic field, and is defined by the following formula:

$$\beta_p \propto \text{plasma pressure}/(\text{plasma current})^2$$

The normalized beta value indicates the maximum index of all beta values which is the overall plasma pressure ratio, and is defined by the following formula:

$$\beta_N \propto \text{plasma pressure}/(\text{toroidal magnetic field x plasma current})$$

If the highest possible plasma pressure, i.e. high output density, can be maintained for a long period of time under a certain toroidal magnetic field and plasma

current, it will be possible to achieve that much more compactness in the reactor (high β_N reactor), which in turn will have a resulting impact on cost. Moreover, when β_p is high, it enables the effective use of bootstrap current which flows naturally according to the pressure gradient along the secondary radial axis. Accordingly, the subject matter of this research on plasma confinement and steady state operation in the JT-60U addresses the question of whether it is somehow possible to achieve a steady state plasma operation having that high an output density.

3. Results from Recent Experiments

3.1 Results of Confinement Research

In the JT-60U, we tried two different methods to improve plasma confinement capability. The first of these was controlling the current and pressure distribution, and the second was adjusting the wall of the vacuum confinement vessel.

The plasma heating experiments in the JT-60U are being carried out using five vertical neutron bombardment injectors (NBIs) and two tangential NBIs as shown in Figure 5. By coordinating the injectors and adjusting the shape of the plasma, we have been able to heat the central part of the plasma to a maximum 40MW. With regard to adjusting the wall of the vacuum confinement vessel (primary wall and diverter plate), we developed and introduced a boronization treatment method whereby the surface of the primary wall was coated with a uniform film of boron by glow discharge with decaborane ($B_{10}H_{14}$) as illustrated in Figure 6. Here, we sought to decrease Z impurities produced at the surface of the wall, and minimize the effect of oxide and other impurities.

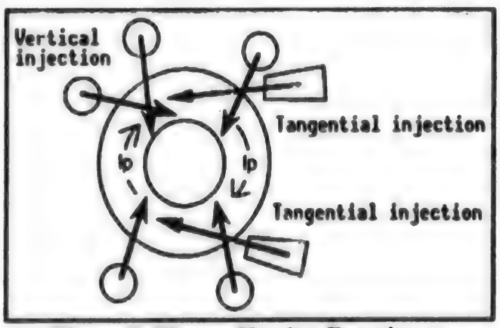

Figure 5. Plasma Heating Experiment

By introducing the techniques described above, we were able to achieve a discharge mode in the confinement improvement research that far surpassed anything that had been achieved before in terms of energy confinement performance. In Figure 7 are shown three plasma confinement modes in the JT-60U. In the L mode, which is the basic confinement mode of tokamak plasma, the pressure and density distribution of plasma show a flat distribution along a transverse section of plasma. The H

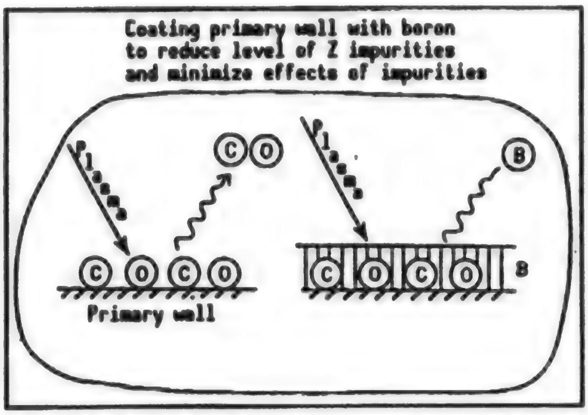

Figure 6. Boronizing Inner Vacuum Confinement Vessel Wall

mode shows relatively improved confinement along the peripheral part of the plasma. The high poloidal beta mode also shows improved confinement at the core of the plasma. In experiments conducted so far in the JT-60U, the three modes described above were achieved independent of each other, but recently we have been able to achieve a new mode, a so-called high-poloidal + H mode, in which the high poloidal and H modes occur simultaneously during a single discharge. This mode has enabled us to achieve better selective heating at the core of the plasma and enabled much less deposition and breaking away of fuel particles on the primary wall than by the aforementioned current distribution control and boronization methods.

As a result, we were able to achieve a fusion product (core ion density x confinement time x core ion temperature), an indicator of plasma performance, that reached $1.1 \times 10^{21} m^{-3} \times s \times keV$ (Figure 8). The respective parameters at that time were as follows:

Core ion density: $4.3 \times 10^{19} m^{-3}$

Energy confinement time: 0.68 s

Core ion temperature: 37 keV

We also achieved an energy confinement that was 3.6 times greater than the L mode. The fusion product and core ion temperature obtained were both world records.

The fusion product has significant meaning, in particular, by the fact that the performance attained therein, which was between one-fifth and one-fourth that required for the goal of spontaneous ignition in experimental reactors (ITER, etc), was obtained with one-twentieth the plasma volume of the ITER (CDA). The conversion of the fusion gain, Q_{DT}, was a maximum 0.6. As things stand now, the performance of plasma is still being inhibited by bursting instability (ELM) produced locally in the peripheral areas due to the rise in plasma density, and by the instability caused by high plasma pressure.

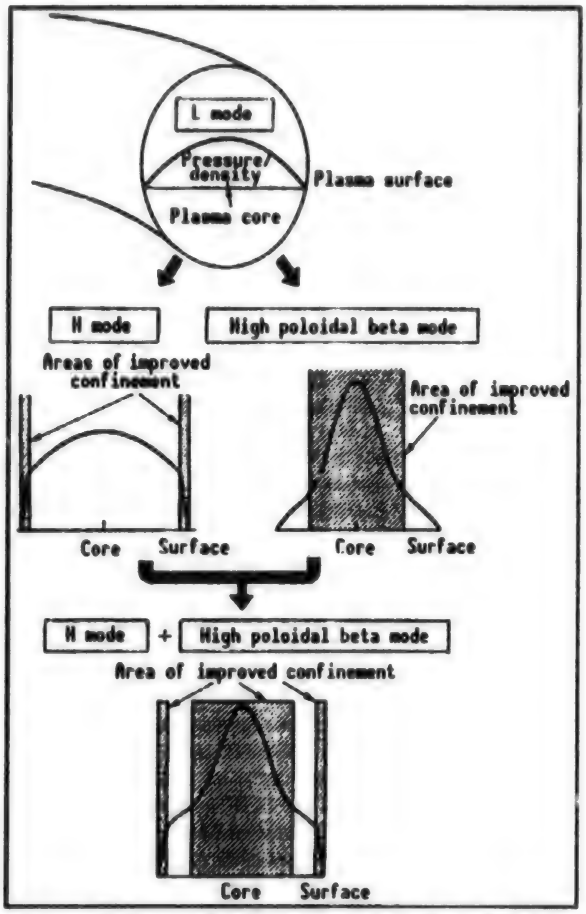

Figure 7. Plasma Confinement Modes (3) of JT-60U

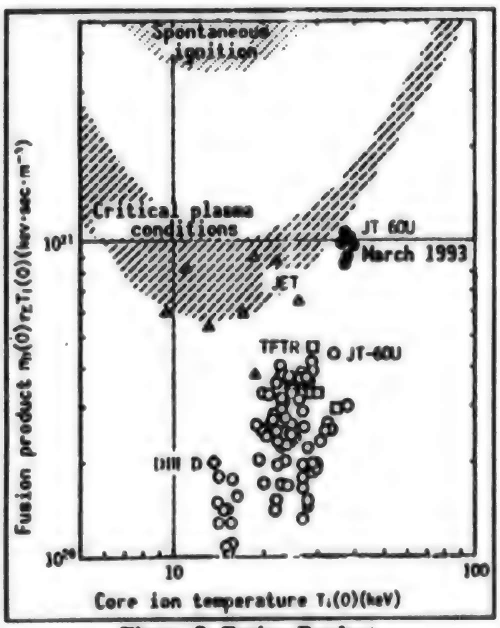

Figure 8. Fusion Product

Looking at the ion temperature distribution in a plasma section in the high poloidal beta + H mode, we can see as shown in Figure 9 that the temperature of the peripheral part of plasma rose more than the high-poloidal mode itself and that an overall higher temperature distribution was achieved. The number of neutrons generated by fusion reactions in the deuterium plasma rose according to the increase in stored energy as shown in Figure 10, with the high poloidal beta and H mode producing an even higher number, reaching a maximum value of 5.6 x 10^{16}/s (equivalent to deuterium fusion reaction output of 65 kW).

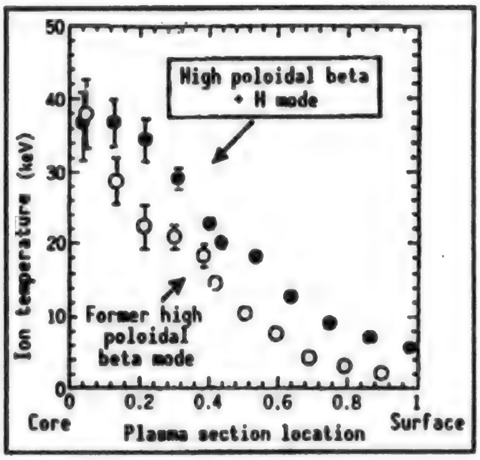

Figure 9. Ion Temperature Distribution in Plasma Section With High Poloidal Beta + H Mode

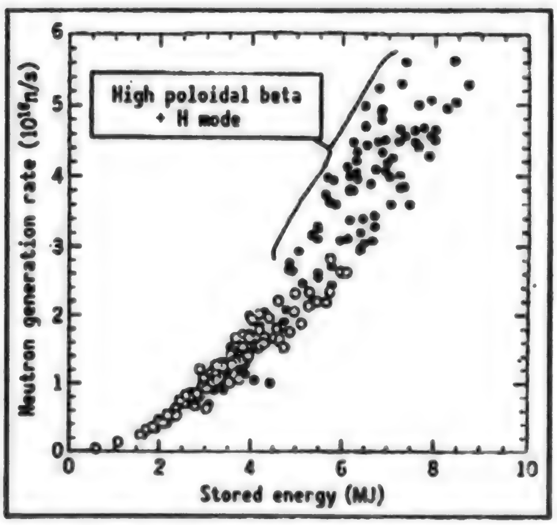

Figure 10. Stored Energy and Number of Neutrons Generated

3.2 Results of Steady State Research

The steady state research is the other research project that is being done alongside the research to improve confinement performance. In conventional tokamak devices, the principle of a transformer is the method used to drive the plasma current (Figure 11 left side). This is a method in which current variations are applied to a poloidal magnetic coil which is equivalent to a primary coil, and magnetic induction causes a transfer of electric energy to the plasma which is equivalent to a secondary coil. In doing this, the plasma offers a certain degree of resistance, so in order to achieve a steady supply of plasma current, the flux that is consumed by plasma must be continuously supplied from the primary side. In actuality, however, current cannot be supplied continuously because there are limits to the electrical capacity of the power supply and coils, so experiments have had to be done on a pulse discharge method with a certain time frame. In the JT-60U facility, the discharge time for a single pulse is a maximum 15 seconds.

The research on a steady state operation aims to develop a method for continuously feeding plasma current that is not based on the principle of the transformer, in other words, one that is not based on electromagnetic induction. The Japan Atomic Energy Research Institute has been doing R&D on a non-induction method using high-energy neutron injection and a high-frequency antenna (Figure 11 upper right).

In tokamak plasma, electrical energy flows naturally without any driving force from the outside merely by the interaction of trapped particles with the current that wants to negate the magnetic field produced by the density gradient along the secondary axis (diamagnetic current). In the research on supplying a steady state current, this spontaneous current is actively used to supply plasma current. The method of supplying steady current by high-frequency antenna is one in which a low-range mixed audio frequency band (2 GHz) is used to create a stream of high-speed electrons at higher and higher frequencies to generate plasma current. The core of the plasma is supplied first with current by high-energy neutron injection. Thereupon, the pressure at the core of the plasma rises, and the area surrounding the core is supplied electrical energy by spontaneous current. The peripheral part of the plasma is then supplied current by the high-frequency antenna. By coordinating these, it becomes possible to achieve a plasma current that extends across an entire plasma section (Figure 11 lower right).

In the section below, we discuss the main results obtained in research to produce a steady state electrical supply under the above scenario.

(1) High Output Density and Steady State Operation

In Section 2 above, we discussed the importance that a high beta value holds in achieving a highly economical and efficient thermonuclear reactor. The normalized

Figure 11. Steady State Research

beta value is an indicator used for increasing the output density of the reactor, and the poloidal beta value, being proportionate to the rate of spontaneous current, becomes an indicator used for decreasing current feeding power. More specifically, by maintaining a high-output density plasma for a long period of time by means of current provided by spontaneous current, it becomes possible to design a compact and inexpensive reactor that uses very little external electrical power. When these values rise, however, we find a lot of instability within the plasma and thus poor confinement, so such instability has to be avoided.

In the JT-60U, by controlling current and pressure distribution within the plasma and making every effort to optimize stability in the H mode, we succeeded in achieving operational stability over a significantly wider range than had ever been achieved (Figure 12). As a result, we were able to produce an operation that simultaneously satisfies both the high normalized beta value (β_N) and the poloidal beta value (β_p) required by a thermonuclear reactor. The maximum beta values we obtained were $\beta_N = 4$ and $\beta_p = 4.3$, respectively. Having a high poloidal beta discharge such as this further enabled us to achieve a complete non-induction current feeding system in which 50 percent of the current is supplied by spontaneous current and 50 percent of the current is supplied at the core of the plasma by neutron injection. This is an extremely important finding that suggests the validity of a steady-state tokamak reactor such as the SSTR[4] based on high output density and a steady state operation.

(2) High-Frequency Current Drive

Ever since the Japan Atomic Energy Research Institute first succeeded in coming up with a method to supply plasma current using low-range hybrid waves in the JFT-2 in 1979, it has continuously paved the way internationally in this research, but in 1993 the outlook got even brighter for the non-induction current feeding system when the current supplied reached 3.6 MA from a previous level of 2 MA (Figure 13). This was due to the introduction of a multielement antenna which enabled a stable injection of high-frequency electrical power reaching a maximum 8.3MW, and this enabled a maximum high-frequency power density of $30MW/m^2$. The other results obtained were demonstrating that the current distribution within plasma could be freely controlled by changing the phases of the incoming electromagnetic waves, and raising to another level the possibility of distribution control by combining spontaneous current with neutron injection induced current.

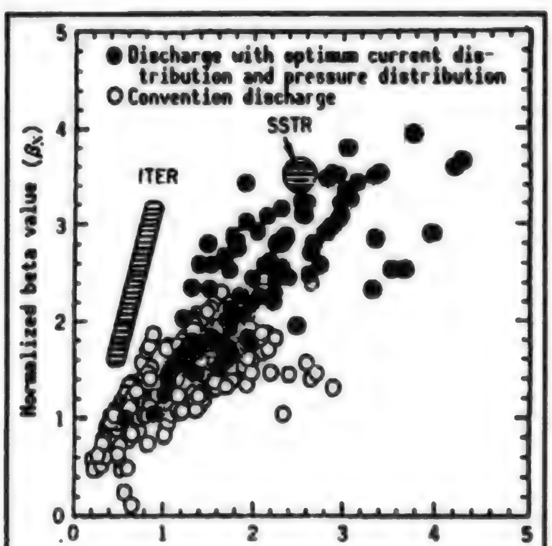

Figure 12. Achieving More Stable Operating Areas by Optimum H Mode Stability

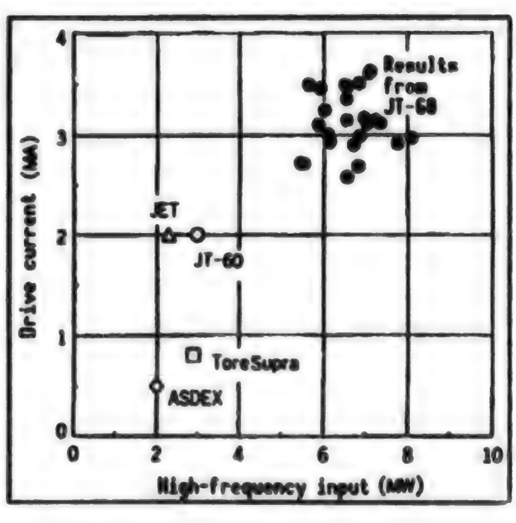

Figure 13. Achieving 3.6 MA Drive Current

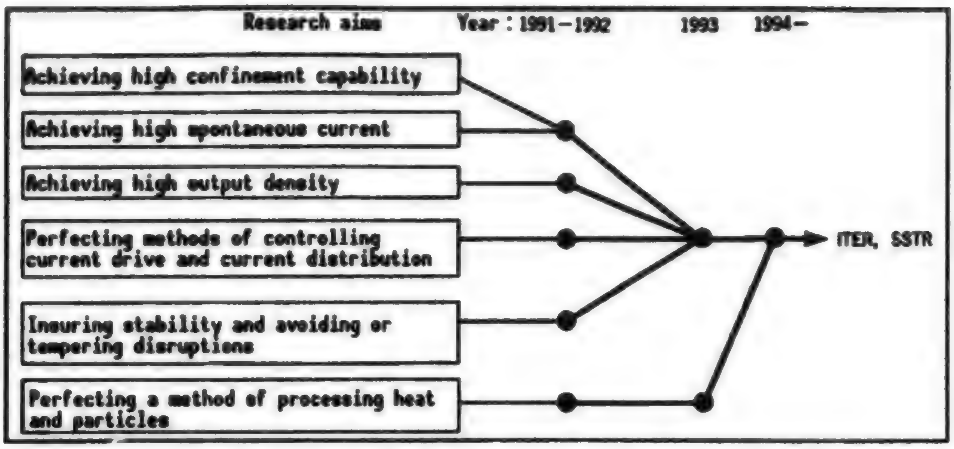

Figure 15. Physical Base Required for Steady State Thermonuclear Reactor

3.3 Other Research

In areas of research apart from what has been discussed above, we continue to see progress being made in controlling the amount of thermal particles appearing in diverter plasma, verifying plasma stability, and limiting disruptions, and are getting closer to perfecting the physical base needed for a steady state thermonuclear reactor such as the ITER in the future and for an ITER engineering design.

4. Radiation Safety

In a tokamak device, the following deuterium fusion reactions produce radiation of neutron and gamma rays. Radioactive isotopes of tritium are also produced.

(1) Generation of 2.4 MeV neutrons and tritium by deuterium fusion reactions

$$D+D \rightarrow {}^{3}He(0.8\ MeV) + n(2.4\ MeV)$$

$$D+D \rightarrow T\ (1\ MeV) + p(3\ meV)$$

(2) Generation of 14 MeV neutrons by deuterium and tritium fusion reactions

$$D+T \rightarrow {}^{4}He(3.5\ MeV) + n(14\ MeV)$$

(3) Generation of ${}^{13}N$ and ${}^{41}Ar$ due to reaction between neutrons and inner chamber air produced by fusion reactions

$${}^{14}N + n \rightarrow {}^{13}N + 2n\ (10\ min\ half\text{-}life)$$

$${}^{40}Ar + n\ {}^{41}Ar + \gamma\ (1.8\ min\ half\text{-}life)$$

(4) Facility Activation and Secondary Gamma Rays Due to Neutrons Produced By Fusion Reactions

Evaluating the effects of radiation is an important problem that murt be understood from the standpoint of assuring work safety in the areas around the facility and within the vacuum confinement vessel. This is especially true with regard to large-scale tokamak facilities where recent test results seem to indicate that core-level plasma performance is reaching critical plasma type conditions. Over the past few years, we have begun taking a closer look at such things as the radiation given off by the facility and the handling of tritium under such conditions in terms of insuring the safety of thermonuclear facilities. Deuterium-tritium experiments (D-T experiments) have already started in Europe and the United States with the JET[5] and TFTR (Tokamak fusion test reactor) that will be seeking to collect large amounts of data on radiation safety. From that standpoint, we also found it necessary to evaluate the effects of radiation with deuterium operations using the JT-60U and to collect useful data for assuring safety in the future.

The equipment of the facility was upgraded for deuterium experiments at the same time that it was retrofitted to increase the level of current. From July 1991 to the time the deuterium experiments started, the JT-60U was regulated as a plasma generating facility for the first time under the Radiation Damage Prevention Act. After that, it underwent inspections over the next two years each time an improvement in plasma performance was achieved. All of the inspections were completed by August 1993. The main measures adopted in this facility are illustrated in Figure 16. In the section below, we discuss the specifics of those measures.

4.1 Neutron Shielding

A portion of the neutrons and secondary gamma rays produced by deuterium reactions penetrate through the walls and roofs of the facility and make their way outside the building where they are scattered and dispersed into the outside atmosphere (skyshine). There is also the effects that radiation passing through the portals on the walls of the confinement vessel have on the work environment in the surrounding laboratory building (streaming). In order to reduce the effects that this type of

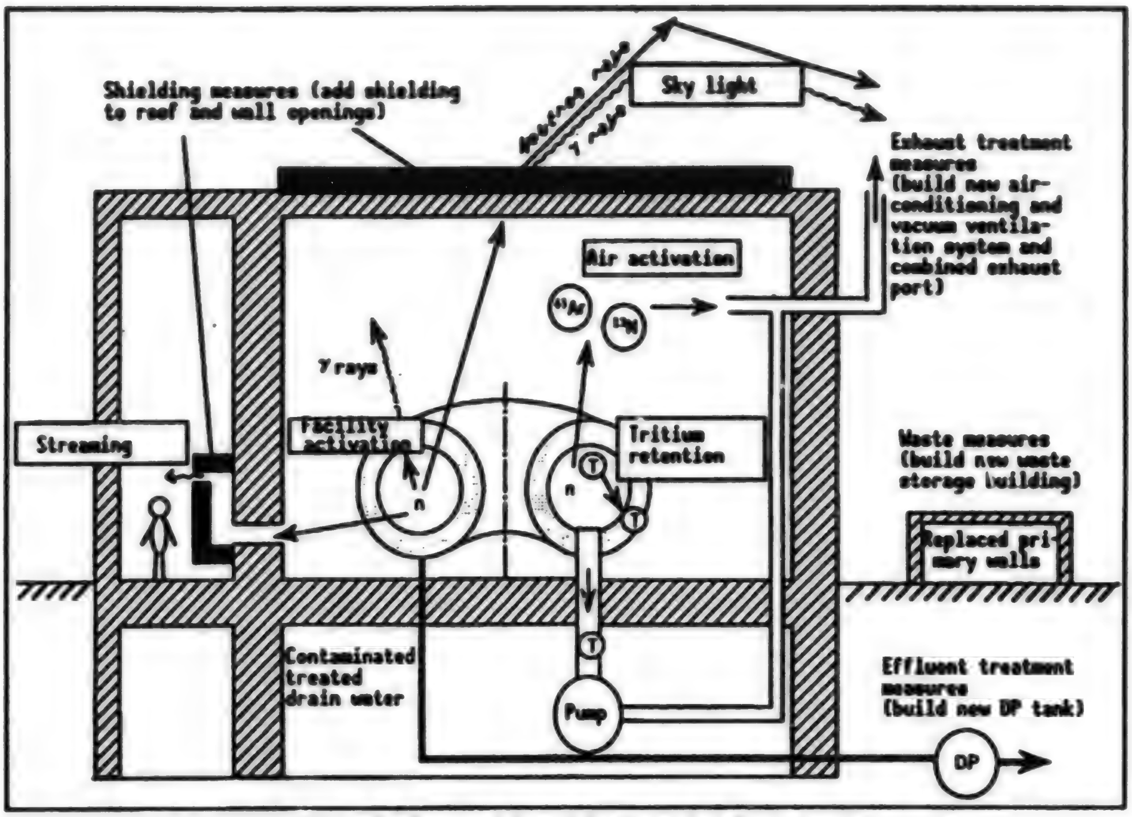

Figure 16. Measure Adopted for Deuterium Experiments

radiation is having on the surrounding environment, we have reinforced the shielding by adding a layer of polyethylene and concrete to the roof of the laboratory building. We have also taken measures to provide additional shielding such as ducting for the portals surrounding the chamber through which pass the communication and power cables for equipment. The dose equivalent rate obtained so far in deuterium experiments, which was measured by the maximum neutron generation rate (5.6×10^{16} neutrons/sec), has fallen well within the legal and targeted levels for the surrounding controlled areas and the property line of the site.

4.2 Generation of Radioactive Isotopes

The radioactive isotopes in gases such as those found in activated air (^{41}Ar, ^{13}N) and in plasma such as tritium which is led outside through a post-production evacuation system each have their own independent evacuation and air conditioning systems, and are discharged together from a newly built exhaust port on the roof of the laboratory building. The minute traces of radioactive isotopes found in contaminated treated water and coolant drain water that are treated as effluent during periodic inspections are being collected in a newly built DP tank and, after being monitored, are then discharged. Implementing these measures has enabled us to keep the actual level of radioactive isotopes in the effluent since the deuterium experiments began to below detectable levels and well within the legal concentration limits. The effluent is also being released at levels that are below detectability and well within allowable concentrations. In the JT-60U, we regularly have to go into the vacuum confinement vessel to make repairs or replace the graphite primary walls, and have built a new waste storage building in which to store the solid waste such as used primary walls that are generated during those routine inspections and maintenance periods.

4.3 Activation of Facility

The 2.4 MeV and 14 MeV of neutrons (1 percent of 2.4 MeV) that are generated by the DD fusion reactions activate the vacuum confinement vessel and surrounding structures of the JT-60U (Figure 17). Figure 18 is a graph showing the calculated rate at which the dose equivalent decreases in structures still activated by residual gamma rays one year after operation of the JT-60U has ceased. As can be seen from the graph, the main nuclide influencing the dose equivalent rate for the first three days after cessation of operations is ^{56}Mn (half-life of 2.6 hours), which is found in the toroidal magnetic coil casings made mostly of Mn steel, and after three days, it is the ^{58}Co (half-life of 70.8 days) in the

Inconel vacuum confinement vessel and the ^{60}Co (half-life of 5.3 years) in the stainless steel base of the primary wall. The contribution of half-life nuclide is to adequately reduce the dose equivalent rate within three days after cessation of operations, so each Monday we have been conducting inspections around equipment in the JT-60U (three days after cessation of deuterium operation).

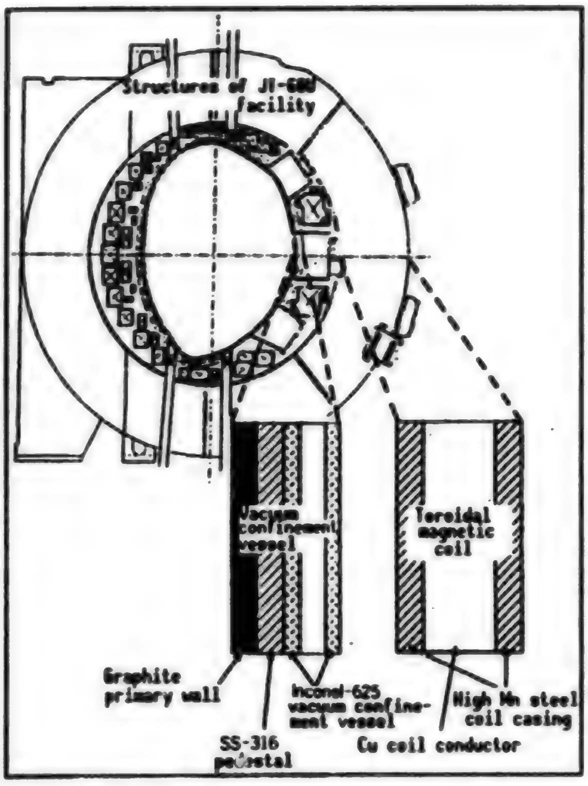

Figure 17. JT-60U Vacuum Confinement Vessel and Peripheral Structures

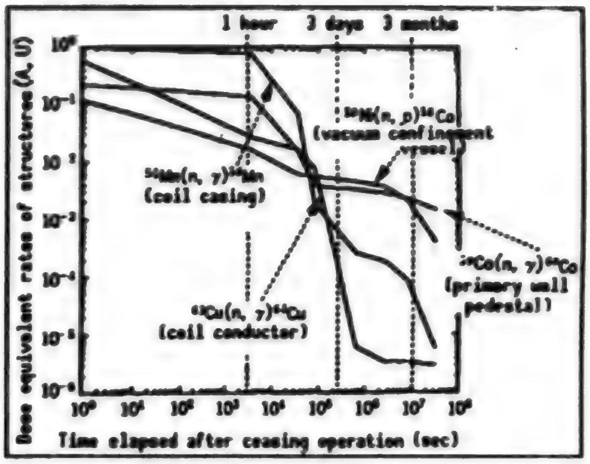

Figure 18. Calculated Time To Reduce Dose Equivalent Rate Elevated by Residual Gamma Rays in Activated Structures of JT-60U After One-Year of Operation

The dose equivalent rate during long periodic inspection work (one to three months after shutdown), such as that which accompanies work inside the vacuum confinement vessel, meanwhile, is determined by long half-life nuclide ^{58}Co and ^{60}Co. Figure 19 is a graph showing the calculated changes in the weekly surface dose equivalent rate of the vacuum confinement vessel during two years of deuterium operations. It shows the strong effect that ^{58}Co with a 70.5 half-life has, and the repeated rise and fall of the dose equivalent rate as documented through four periodic inspections conducted since neutrons started being generated and deuterium experiments first started in July 1993 (Figure 19 A-D). The long half-life nuclide, ^{60}Co, found in the stainless steel pedestal of the primary wall increases proportionate to the amount of neutrons and produces a residual storage of radioactivity.

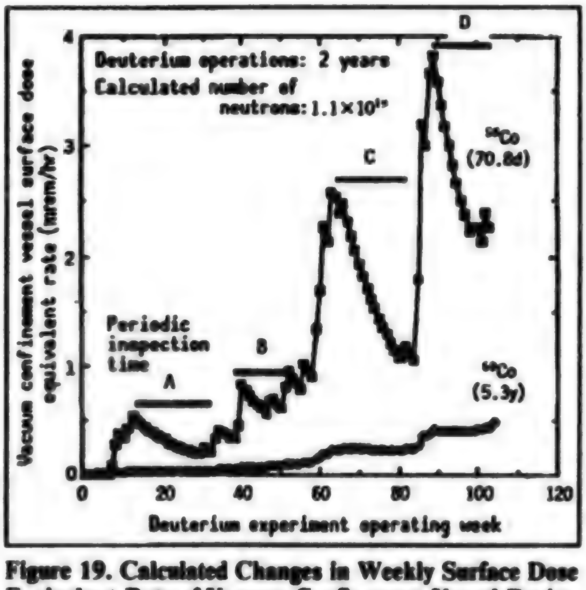

Figure 19. Calculated Changes in Weekly Surface Dose Equivalent Rate of Vacuum Confinement Vessel During Two Years of Deuterium Operations

In doing periodic inspections in conjunction with the work being done inside the vacuum confinement vessel, we allow for a cooling off period of approximately one month after running experiments and wait for the decay of ^{58}Co before beginning work inside the vacuum confinement vessel. The actual dose equivalent rate on the surface of the vacuum confinement vessel during four periodic inspections has tended to gradually increase due to effects which have been shown to be long-lived nuclide. These are, nonetheless, still below 30 μSv/hr and have not reached the level where it will hinder inspection work (Figure 20).

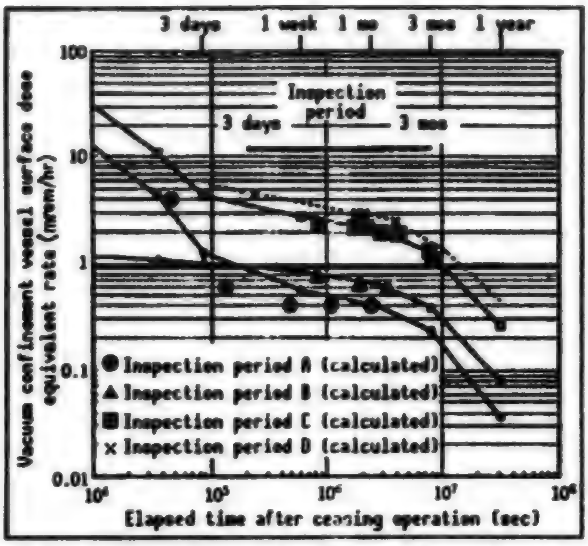

Figure 20. Decay Time of Vacuum Confinement Vessel Surface Dose Equivalent Rate After Cessation of Operation

4.4 Tritium Retention

The amount of tritium generated in plasma over two years of deuterium experiments was roughly 20 GBq. This tritium passes through an evacuation system and is discharged outside after being diluted, but a portion of the tritium is retained within the graphite primary wall inside the vacuum confinement vessel. In order to ensure the safety of operation maintenance, it is necessary to remove the tritium from the primary wall before beginning work inside the vacuum confinement vessel. Figure 21 is a timeline showing the experiments conducted during the year with the JT-60U, but between May and November or December when we perform routine inspections, we have been conducting tritium degassing operations using hydrogen or helium gas that take about one month to perform using the aforementioned cooling off period for ^{58}Co.

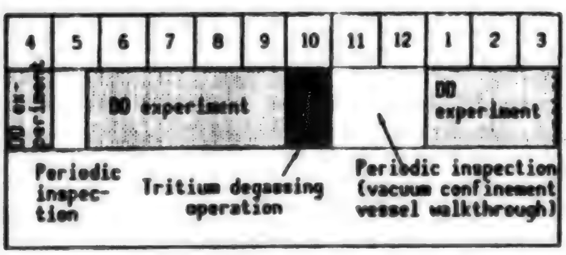

Figure 21. Operating Schedule for JT-60U Experiments (year)

Figure 22 is a graph showing the variations over time in tritium concentration in a single day of degassing operations. The lower horizontal bar represents the experimental discharge time based on hydrogen gas, and the upper bar represents the glow discharge cleaning with helium gas that is done one day after experiments are completed.

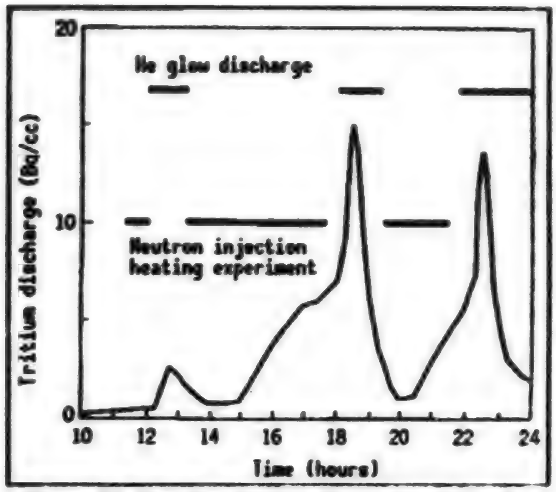

Figure 22. One-Day Tritium Degassing Operation

Glow discharge cleaning involves cleaning the entire inner surface of the vacuum confinement vessel and is done between experimental discharges in order to maintain a good plasma discharge condition. The diverter discharges in the JT-60U produce a lot of heat and particles within the plasma that are concentrated on one portion of the diverter plate, so while tritium is deposited over the entire surface on the one hand, a lot is also stored within the graphite walls of the diverter plate. Accordingly, though the initial helium glow discharge is short, the tritium is removed very effectively from the entire inner surface of the vacuum confinement vessel. As the experiment progresses, the diverter plate is heated by repeated discharges and tritium is gradually discharged from the inside of the graphite walls. In glow discharges after the second, it is not only the surface that is heated but the diverter plate as well, achieving a much more effective removal of gas containing the tritium near the surface. In other words, the helium glow discharge could be considered an effective degassing method for removing tritium from the entire graphite wall surface in the vacuum confinement vessel, and heating the graphite walls by repeating experimental discharges could be an effective way to remove tritium from the inside of the graphite walls (diverter plate mainly).

After measuring the amount of tritium discharged during degassing and during deuterium discharges and measuring the amount of tritium that is mixed in with the vacuum pump oil, we came up with the tritium flow depicted in Figure 23. This enabled us to estimate that the amount of tritium retained in the primary wall was about 70 percent of the total 20 GBq that was produced up till then in the plasma. Though there is an extremely

small discharge of tritium from inside the vacuum confinement vessel at room temperature, the tritium content within the confinement vessel when opening the vacuum confinement vessel to the atmosphere is less than one-fifth the content limit of tritium oxide and has no effect on work being done inside the confinement vessel.

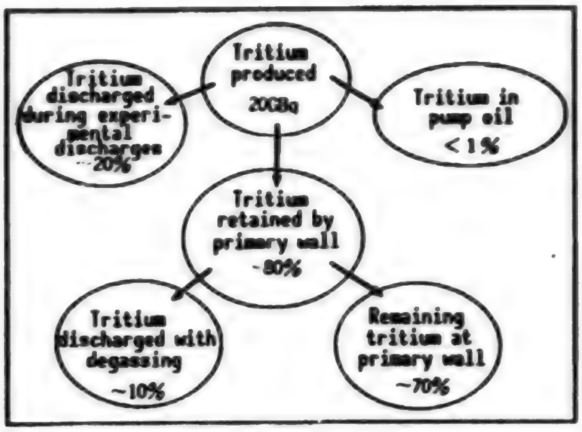

Figure 23. Tritium Flow

Conclusion

A great deal of progress has been made in confinement improvement research and steady state research being done with the JT-60U critical plasma test facility. At present, we are in the process of making preparations to install a 500 keV negative-ion NBI with the aim of putting the facility into operation by 1995. In the future, we plan to push ahead with research on ways to further improve plasma performance and on non-induction methods of supplying current by NBIs or low-range hybrid waves. In addition, we will be contributing to advanced research on an ITER engineering design and a steady state thermonuclear reactor which will involve research on heat removal from a diverter under super-hot input conditions and on alpha particles produced by D-He reactions. We will also be making an effort to collect more data on activation and tritium behavior in continuing work to improve safety.

[Boxed item, p 46]

Research Team Formed in JAERI To Elucidate Superconducting Phenomena in Uranium Oxide

A research team created within the Japan Atomic Energy Research Institute to study uranium oxide superconduction has embarked on research at the High-Tech Basic Research Center [Sentan Kiso Kenkyu Senta] to elucidate superconducting phenomena in uranium oxide.

The project leader is Dr. A. Onuki, a professor of science at Osaka University. Also taking part in the project will be six other research assistants, one of which was invited to be a full-time researcher. Superconducting phenomena in uranium oxide has been attracting a lot of attention worldwide as unusual types of oxides that exhibit antiferromagnetic properties yet give rise to superconduction. Being able to elucidate this phenomena will go a long way toward solving the mystery of superconducting phenomena in high-temperature yttrium- and bismuth-based superconductors. That is why the Ministry of Education has submitted a new research project called "Physics of Closely Correlated Superconducting Systems," which falls under a special category of key research eligible for scientific research funding (representative: Dr. T Komatsubara, Tokyo University).

The JAERI High-Tech Basic Research Center was opened in April 1993 in order to do research on nuclear energy in new and uncharted areas, and to take the lead worldwide in such research. It is currently working on 12 research projects including ones on molecular science, actinoid solutions, ion beam biogenetic research, hadron transportation, and radiation surface chemistry.

This research to study uranium oxide superconducting phenomena will make the 13th project.

The group will manufacture uranium oxides which have indicated up to 10 different types of superconducting phenomena including platinum-uranium, barium-uranium, germanium-uranium, nickel-uranium, and cobalt-uranium, and will then investigate the physical characteristics. These uranium oxides all exhibit superconducting phenomena at or near 1K, while at the same time also having antiferromagnetic properties. The group is planning to study the movement of electrons that exhibit this complex phenomenon. It also has plans to do research in which it will purify the uranium needed for experiments and use the purified uranium to create simple crystals of uranium oxide, and also purify uranium by the electro-transport method.

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Scenario To Use FBR in Japan

95FE0227A Tokyo GENSHIRYOKU KOGYO in Japanese Sep 94 pp 53-63

[Article by Fumishige Yoneda, Power Reactor and Nuclear Fuel Development Corp., Planning Director]

[FBIS Translated Text]

1. Purpose of Study

The government released its long-term plan recently concerning the research, development and use of nuclear power. The long-term plan, which is primarily a range of studies until the year 2030, is being implemented with the aim of developing and coordinating fuel cycle technologies and perfecting the technical systems for fast breeder reactors (FBR) so that these reactors can be put into commercial use by the year 2030.

It will then use these studies to prepare the technical systems for plutonium recycling which will involve fast breeder reactors and the fuel cycle thereof, and to determine what the overall configuration of the fast breeder reactor system, light water reactor system, and nuclear energy supply system, which will be made up of these fuel cycles, should be in an era in which fast breeder reactors are being developed on the basis of being put into commercial use by the year 2030.

There are many people who believe that there are too many uncertainties and that it is senseless to be planning out this far in the future. We believe it extremely important, however, to try to create a future image of fast breeder reactors and the fuel cycle thereof in order to help us understand what it means to put these reactors into service and in order to help us set goals regarding the R&D to be done.

In this paper, we take a closer examination of fast breeder reactor use in Japan based on this long-term plan and discuss the future outlook for these reactors until the year 2100.

2. Necessity of Uranium Resources and FBR Development

Figure 1 is a graph showing the relationship between the total uranium demand and amount of resources in the free world until the year 2030. The demand curve in the graph is based on the estimated demand for natural uranium which was presented in the 1989 edition of the OECD/NEA Redbook which did a study on high and low growth scenarios for nuclear power plants in the free world. The uranium resource amounts, meanwhile, were taken from the 1992 edition of the Redbook. The total uranium demand around the year 2030 is nearly equal to the total amount of resources.

What is important to note here is that this graph represents only the uranium demand until the year 2030 that will be needed by reactors that are to be built up to 2030. It must be remembered that there will be demand for

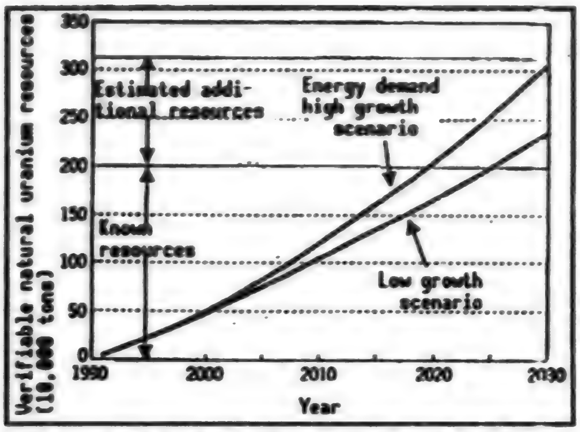

Figure 1. Natural Uranium Demand and Verifiable Uranium Resources in Free World (as of 1991) (source: 1989 and 1992 OECD/NEA Redbook)

uranium from these reactors to be built by the year 2030 and after the year 2030 as well. If we assume the life of an existing reactor to be 40 years and the average useful life at the 2030 year mark to be 20 years, we estimate that uranium demand after the year 2030 will be 2 million tons in the case of high growth and 1.4 million tons in the case of low growth. If we were to add the demand of reactors that are to be built up to the year 2030, the uranium demands would climb to 4-5 million tons. It is our feeling that the uranium needed after the year 2030 will have been secured by long-term contracts on uranium supplies at the 2030 year mark. Therefore, we believe that there is a good chance that the supply of uranium will start tightening up from the year 2030.

The fast breeder reactor, which will gradually replace the light water reactor after being put into commercial use, will need an appropriate period of time after being introduced until they are able to assume a central role in supplying energy. For that reason, it will be necessary to start putting fast breeder reactors into service much sooner when uranium resources start tightening up.

There are, on the other hand, quite a few people who share the opinion that there will be no shortage of uranium resources because if the balance of supply and demand is upset it will only lead to further uranium exploration and new resources being discovered. It is our feeling that if a large quantity of new uranium resources were to be discovered that that would only delay the issue that much more. Does it not imply that adopting an optimistic scenario such as this of merely waiting for fortune to strike is nothing but an indication of the possibility of a tightening of uranium supply and demand?

From what we have just seen, it is vitally important that we prepare for the eventuality of tighter uranium supply and demand and that we begin working on the technical systems so that FBR plutonium recycling can be put into commercial use by the year 2030.

3. Premises of Study

The study was based on the following premises:

(1) Characteristics of Reactors

The characteristics of reactors are listed in Table 1. The characteristics of future reactors have not been determined with any degree of certainty and so we have made various assumptions, and in doing so have tried to use the most recent data available.

In terms of light water reactors, we did our estimates based on an 83 percent facility usage rate involving advanced light water reactors (ABWR, APWR). We also factored in the use of advanced light water reactors in our estimates on Pu-thermal reactors. The shift to advanced light water reactors and the pace at which that change will take place have not been made clear, so in our projections we used advanced light water reactors for all light water reactors after 1990. The light water reactors that went into service prior to 1990 were given the reactor characteristics of advanced light water reactors built after 1990. We lumped gas reactors and commercial advanced thermal reactors in with light water reactors. The burnup of a fast breeder reactor was estimated to be 150,000 MWd/t.

Table 1. Table of Model Reactor Characteristics

Reactor type		BWR	PWR	Pu-thermal (BWR)	Pu-thermal (PWR)	FBR		
						Core	Axial [blanket]	Radial [blanket]
Electrical output	(MWe)	1000	1000	1000	1000		1000	
Thermal efficiency	(%)	33.4	34.0	33.4	34.0		40	
Specific power	(MWt/t)	24.8	38.3	24.8	38.3			
Burnup	(MWd/t)	45,000	48,000	45,000	48,000		Approx. 150,000	
Fuel in-core residence time	(years)	6.0	4.14	6.0	4.14			
Breeding ratio/Conversion ratio							1.21	
Number of batches						3		4
Plant usage rate	(%)	83	83	88	87		90	
Initial fuel loaded								
Heavy metals	(t)	120.9	76.7			36.130	22.370	16.002
Uranium	(t)	120.9	76.7			29.789	22.370	16.002
Plutonium	(t)	0	0			6.341	0.0	0.0
Fissionable plutonium	(t)	0	0			4.286	0.0	0.0
Uranium enrichment	(%)	2.4	3.2			0.3	0.3	0.3
Equilibrium fuel loaded								
Heavy metals	(t/yr)	21.3	18.5			6.022	3.728	2.000
Uranium	(t/yr)	21.3	18.5	6.45	5.87	4.964	3.728	2.000
Plutonium	(t/yr)	0	0			1.057	0.0	0.0
Fissionable plutonium	(t/yr)	0	0	0.435	0.411	0.715	0.0	0.0
Uranium enrichment	(%)	3.9	4.6	0.711	0.711	0.29	0.30	0.30
Initial fuel removed								
Heavy metals	(t/yr)	20.7	16.5			5.702	3.720	1.996
Uranium	(t/yr)	20.6	16.3			4.680	3.650	1.966
Plutonium	(t/yr)	0.17	0.15			1.022	0.069	0.031
Fissionable plutonium	(t/yr)	0.11	0.11			0.673	0.067	0.030
Uranium enrichment	(%)	0.58	1.00			0.20	0.25	0.25
Equilibrium fuel removed								
Heavy metals	(t/yr)	20.3	17.6			5.110	3.671	1.966
Uranium	(t/yr)	20.1	17.4	6.27	5.68	4.131	3.478	1.867
Plutonium	(t/yr)	0.21	0.21			0.972	0.193	0.100

Table 1. Table of Model Reactor Characteristics (Continued)

Reactor type		BWR	PWR	Pu-thermal (BWR)	Pu-thermal (PWR)	FBR		
						Core	Axial [blanket]	Radial [blanket]
Fissionable plutonium	(t/yr)	0.13	0.15	0.270	0.263	0.616	0.176	0.090
Uranium enrichment	(%)	0.68	1.07			0.08	0.17	0.16
Decommissioned reactor fuel removed								
Heavy metals	(t)	117.1	74.0			32.409	22.169	15.851
Uranium	(t)	116.1	73.3	35.88	22.67	26.417	21.353	15.320
Plutonium	(t)	0.96	0.73			5.991	0.816	0.531
Fissionable plutonium	(t)	0.69	0.56	1.836	1.205	3.873	0.761	0.494
Uranium enrichment	(%)	1.36	1.79			0.14	0.21	0.22
Comments				MOX fuel	MOX fuel			

(2) Operating Plan for LWR Spent Fuel Reprocessing Plants

A 800tU/yr reprocessing plant will be put into operation around the year 2000. That will increase to 1600 tU/yr by the year 2027. After 2027, the plutonium recovered will be supplied to the fast breeder reactor system.

The plutonium recovered prior to 2026 will be used for research and development of Pu-thermal reactors.

(3) Estimates on Nuclear Energy Production

The total amount of energy to be generated by nuclear power plants in Japan in the year 2010 was estimated at 70 million kilowatts based on the findings of a subcommittee on energy supply and demand in the MITI Advisory Committee for Energy. The figure for the year 2030 was estimated at 92 million kilowatts according to the Japan Atomic Energy Commission (JAEC), the details of which were debated by a subcommittee set up to study basic problems within the committee for long-term planning of nuclear energy development. The figures used for the years between 2010 and 2030 were estimates based on linear growth. The annual growth during that time was estimated at 1.1 million kilowatts per year. The figures after the year 2030 were based on a number of factors.

(4) Life of Reactors

The life of all light water reactors and fast breeder reactors was based on a 40-year life span.

However, there is a large wave in the amount of energy produced by existing reactors and reactors being planned depending on the year, so what we have done is to adjust the life of individual reactors so that no wave is produced because of decommissioned reactors and so that the average life of a reactor is 40 years.

(5) Demonstration Reactor Plan

The study was based on a first demonstration fast breeder reactor (660,000 kW) being put into operation by the year 2009, and a second demonstration reactor (million kW) being put into operation by the year 2020. We calculated that the reprocessing of spent fuel for the demonstration reactors would begin at the same time that the spent fuel of the first demonstration reactor starts being reprocessed.

(6) Pace of FBR Demonstration Reactor Introduction and Plutonium Balance

Fast breeder reactors will be put into service to the degree that plutonium is available from reprocessing LWR spent fuel. In other words, fast breeder reactors will be put into use at a pace so as to prevent a plutonium surplus or shortfall.

(7) Characteristics of Fast Breeder Reactor and FBR Fuel Cycle

The study included 1.2 and 1.3 breeding rates, and one-year, two-year, and three-year out-of-core cycle times.

The out-of-core cycle is the time it takes for spent fuel to be removed from a reactor, remanufactured into fuel after reprocessing, and loaded again into a reactor.

The fuel cycle is designed so that nuclear reactors and fuel cycle facilities are located near one another and are built on the same scale as each other. For example, if we were to build a fast breeder reactor in the millions of kilowatt class at one location, we would consider building a fuel cycle facility next to it that had a capacity of hundreds of tPuf per year.

The capacity of a fuel cycle facility is measured in tPuf which represents the number of tons of fissionable plutonium.

4. Projection of LWR Energy Production and Uranium Need

(1) Projected Energy Production of Light Water Reactors

Figure 2 is a graph projecting that the amount of nuclear energy produced by light water reactors in Japan will

reach 92 million kilowatts by the year 2030. After 2031, we envision only fast breeder reactors being built and no new light water reactors. Assuming the life of a reactor to be 40 years, light water reactors should still be in operation until the year 2070. The average rate at which reactors will be decommissioned for the 40 years after 2030 will be about 2.3 million kilowatts per year. This is based on a first FBR, a 660,000-kW reactor, being put into operation by the year 2009, and a second FBR, a million kW reactor, being put into operation by the year 2020.

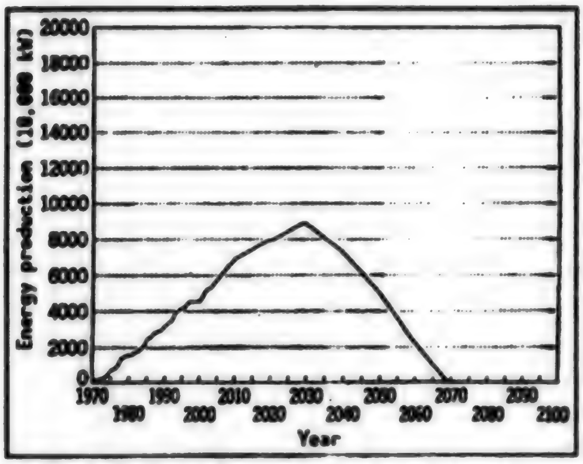

Figure 2. Projected Energy Production of Light Water Reactors

(2) Natural Uranium Requirements

The line (a) in Figure 3 represents the total amount of natural uranium that will be needed by light water reactor system. The calculations were based on a 0.2 percent U235 concentration of depleted uranium during enrichment. Given the current situation, however, we have decided to use 0.25 percent from 1990 until 2004 when fuel is loaded. The study is further premised on reusing uranium by the enrichment of uranium recovered through reprocessing, assuming a 0.2 percent U235 concentration of depleted uranium during enrichment. The total amount of uranium needed, including the approximately 70,000 tons of uranium loaded into reactors through to 1989, is 660,000 tons.

Of that amount, we can see that the 590,000 tons needed after 1990 means that Japan will be using almost 30 percent of the verifiable uranium resources in the free world by itself as illustrated by Figure 1 showing the amount of known uranium in the world as of 1990. If we take into account the fact that nuclear energy production in the world will continue growing and that Asian countries will begin using nuclear energy, it becomes apparent that considerable effort must be made to secure the necessary uranium.

Another thing to be considered is the fact that 0.2 percent was used in calculating the U235 content of depleted uranium during enrichment after the year 2005, but if 0.25

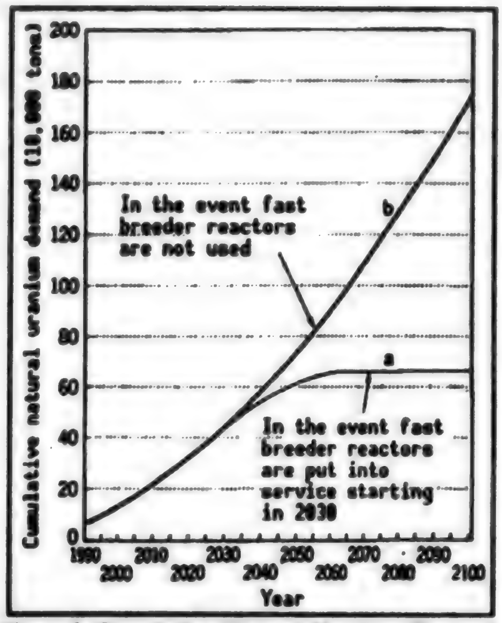

Figure 3. Cumulative Natural Uranium Demand

percent were used instead, the amount of natural uranium that Japan would need after the year 2005 would be 710,000 tons, which would be approximately 7 percent less than the previous estimate. The amount of natural uranium that would be needed, assuming that recovered uranium from enrichment would not be used, is about 800,000 tons, which means that by using recovered uranium Japan would need 17 percent less natural uranium.

5. LWR Spent Fuel Reprocessing and Plutonium Committed to FBR System

(1) LWR Spent Fuel Reprocessing

According to the estimates made in Section 4.1 above, light water reactors will produce spent uranium fuel according to line (a) in Figure 4, and reprocessing plants will need to process a total of 95,000 tons of uranium. The operation of these plants is estimated on the changes indicated by line (b). After fast breeder reactors come into use, approximately 11 tons of plutonium (Puf) will be obtained yearly by reprocessing 1600 tons of uranium per year. The reprocessing of spent MOX fuel is discussed in a separate section below (3).

Line (b) in Figure 4 includes both the reprocessing of LWR spent fuel at the PNC Tokai Reprocessing Plant (cumulative total of 1090 tU after 1990) and that done in both England and France (cumulative total of 5400 tU after 1990).

(2) Storage Amount of LWR Spent Fuel

The changes in the amounts of stored spent uranium fuel from light water reactors are shown by line (b) in Figure 5. In Figure 5, line (c) shows the amount of fuel being loaded as the yardstick for determining the amount of spent fuel to be stored.

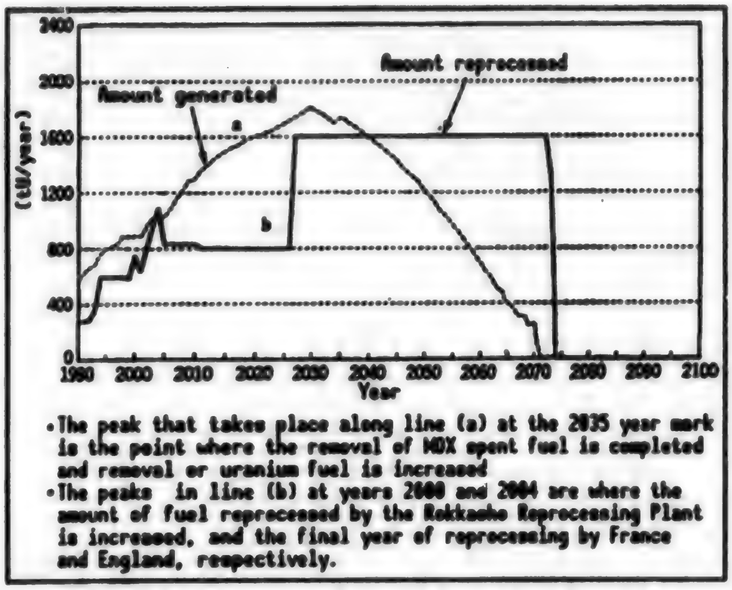

Figure 4. Generation and Reprocessing of LWR Spent Fuel

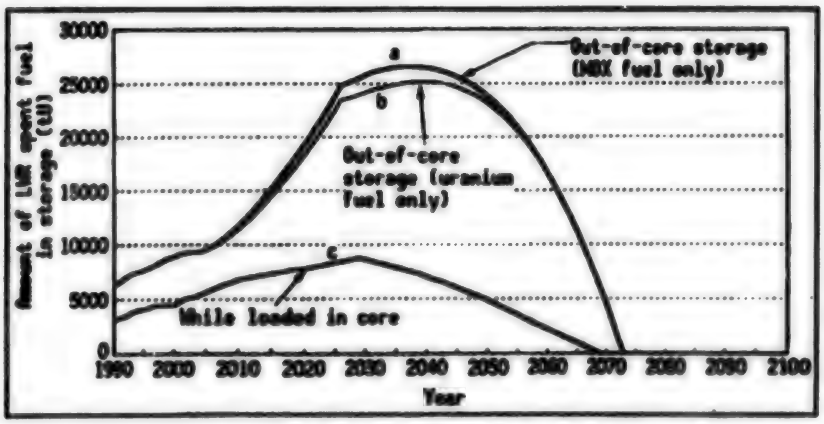

Figure 5. Storage of LWR Spent Fuel

(3) Pu-Thermal, Etc

A detailed schedule has not been determined yet regarding Pu-thermal reactors and reprocessing the spent fuel thereof, so we have used simplified estimates. Specifically, we estimated that one-third of a core of MOX fuel will be loaded into light water reactors with a 10 million kilowatt output between the years 2000 and 2029.

Pu-thermal reactors will generate approximately 1850 tons of spent uranium, but apart from spent uranium fuel, we have estimated that they will reprocess and recover 2.7 tons of fissionable plutonium evenly divided by year between 2032 and 2061 after fast breeder reactors are put into service, and this will be used for putting fast breeder reactors into use.

This is based on a total of approximately 13 tons of fissionable plutonium evenly divided by year to be recovered during the same period from "Monju" fuel, ATR fuel, and the fuel loaded into FBR demonstration reactors until 2029, and an additional 3.1 tons of fissionable plutonium that will be recovered and used annually.

We have estimated that one-third of all fuel assemblies in the core of Pu-thermal reactors will be configured with MOX fuel pins. When Pu-thermal fuel assemblies are

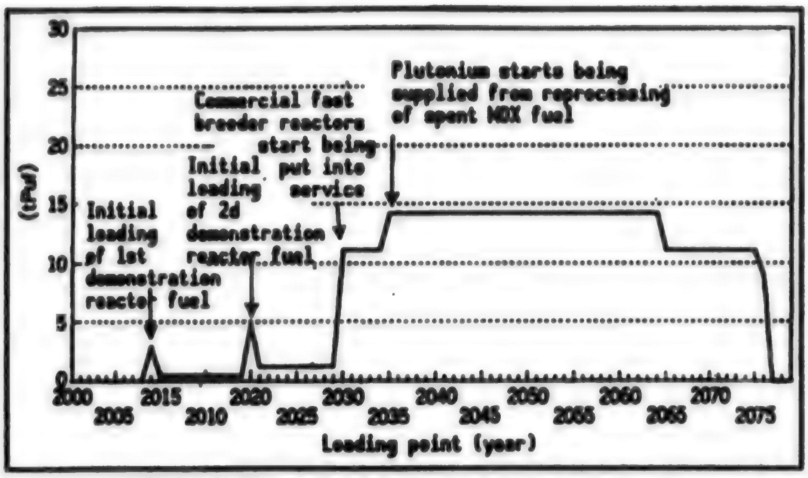

Figure 6. Yearly Input of Plutonium to FBR System

configured with MOX fuel pins and uranium fuel pins, the amount of spent MOX fuel increases and amount of spent uranium fuel decreases to the degree that spent MOX fuel is included in the uranium fuel pin.

(4) Plutonium Committed to FBR System

In Figure 6, we show the changes in plutonium inventories as plutonium is obtained from LWR uranium fuel reprocessing and Pu-thermal MOX fuel reprocessing and is put into the FBR system.

6. Characteristics Required by FBR and Fuel Cycle for Putting Required Level of FBRs Into Service Using Plutonium Committed to FBR System

(1) Required Level of FBRs

The required level of FBRs to be put into service will vary depending on how much nuclear energy is needed to sustain a certain level of growth. In Figure 7, we show three different scenarios for putting FBRs into service.

1. Line (a): Nuclear energy production increases at the rate of 1.1 million kilowatts per year after the year 2030 (hereinafter fast growth scenario)
2. Line (b): Nuclear energy production increases at the rate of 550,000 kilowatts per year after the year 2030 (moderate growth scenario)
3. Line (c): Nuclear energy production levels off at 92 million kilowatts after the year 2030 (low growth scenario)

(2) Possible FBR Implementation Scenarios and Characteristics Demanded of FBR and Fuel Cycle

Possible FBR Implementation Scenarios

In Figures 8 and 9, we show possible FBR implementation scenarios in which all the plutonium committed to the FBR system is used without any surplus remaining and fast breeder reactors are put into service after the year 2030. The parameters used were the breeding ratio,

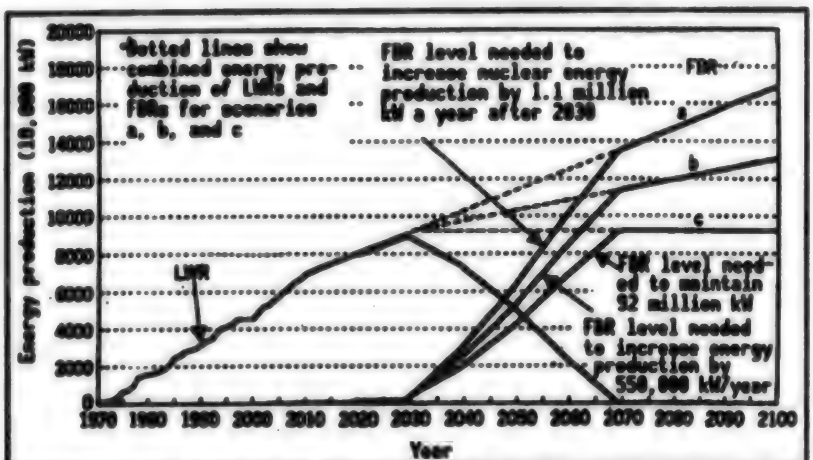

Figure 7. Required Level of FBR Power Plants

which is a characteristic of the reactor, and out-of-core cycle time, which is a characteristic of the fuel cycle. The fast breeder reactors would be put into service in such a way that all the spent fuel is processed quickly and all the recovered plutonium is recommitted to the system.

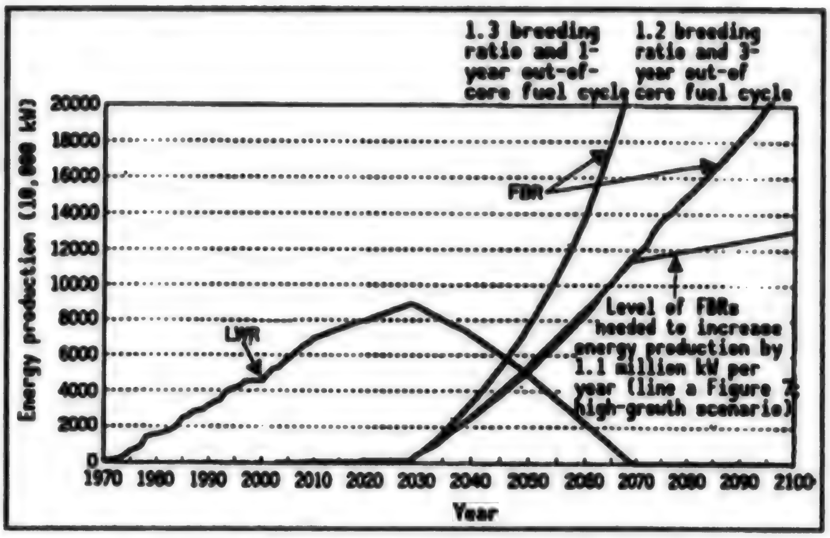

Figure 8. Possible FBR Implementation Scenario (1)

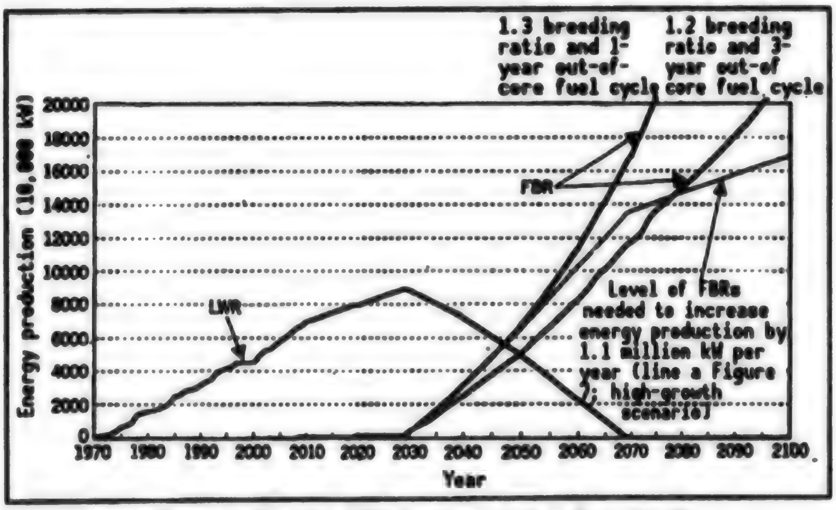

Figure 9. Possible FBR Implementation Scenario (2)

In other words, there would be no excess plutonium produced after the year 2030. The plutonium recovered prior to 2030 would be used for research and development of Pu-thermal reactor use, and so no excess plutonium would be produced.

Desired Characteristics of FBR and Fuel Cycle in Moderate and Fast Growth Scenarios

As we can see from Figure 8, a breeding ratio of 1.2 and an out-of-core cycle of three years in the moderate and low growth scenarios just about enables us to introduce the required level of fast breeder reactors.

Desired Characteristics of FBR and Fuel Cycle in Fast Growth Scenario

As we can see from Figure 9, a breeding ratio of 1.2 and an out-of-core cycle of one year in a fast growth scenario almost gives us the ability to introduce the required level of fast breeder reactors. A 1.3 breeding ratio and two-year out-of core cycle also gives us just about the same FBR possibility curve. A two-year out-of-core cycle with a 1.2 breeding ratio, however, is unable to provide adequate coverage using fast breeder reactors.

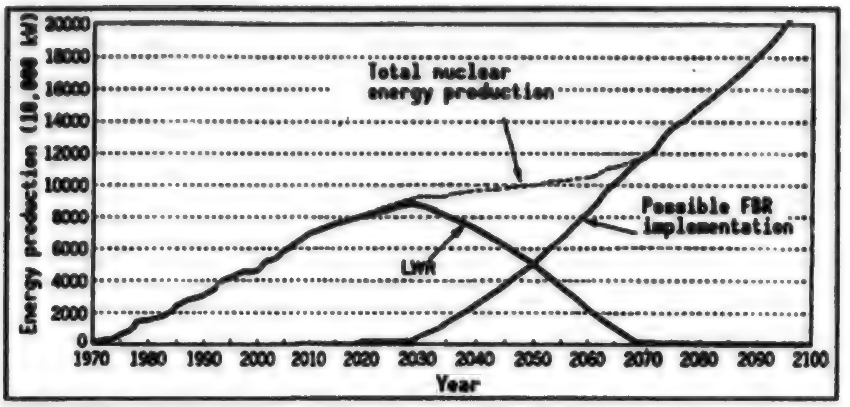

Figure 10. Possible FBR Implementation Scenario (3) (1.2 breeding ratio and three-year out-of-core fuel cycle)

Changes in Total Nuclear Energy Production (1.2 breeding ratio and three-year out-of-core cycle)

In Figure 10, we show the changes in the total energy production by the use of fast breeder reactors and light water reactors using a 1.2 breeding ratio and three-year out-of-core cycle.

In the period where there are both light water reactors and fast breeder reactors, there will be need to replace the light water reactors that have reached the end of their useful life with fast breeder reactors, so there is a limit to the plutonium that can be used to increase the total nuclear energy production.

It will be possible to achieve a relative increase in the rate at which nuclear energy production grows after the year 2070 when there will be no more light water reactors and only fast breeder reactors. It will be a scrap and build era of fast breeder reactors with no light water reactors. We will be able to transfer the plutonium from scrapped fast breeder reactors to new reactors, so the plutonium bred can be used to increase the number of plants. For that reason, despite the fact that there will be no plutonium being supplied from light water reactor spent fuel, it will be possible to achieve a relative increase in the rate at which nuclear energy production is growing. For example, in the scenario given in Figure 10, the average rate of growth in the 30 years after 2070 will be 2.1 percent, and the time it takes for compound interest to double will be 33 years.

7. Strategies for Putting Fast Breeder Reactors Into Service

(1) When Demand Is Less Than Possible Energy Production

The curves in Figures 8 and 9 represent possible nuclear energy production levels, and when demand is less than these amounts, the level at which fast breeder reactors are put into service will be reduced to compensate for that. In that event, the amount of plutonium being recovered will be adjusted and the plutonium balance restored by reducing the breeding ratio and extending the out-of-core fuel cycle so that there is no excess plutonium.

(2) When Demand Is Greater Than Energy Production Capacity

In the event that demand should exceed power plant generating capacity, it will be possible to step up the tempo of fast breeder reactors by enlarging the breeding ratio and shortening the out-of-core cycle time, and put new reactors into service according to the demand for nuclear energy. There will be a need to develop the technologies to make this possible.

8. Various Scenarios

(1) Without Fast Breeder Reactors

In order to insure growth of 1.1 million kilowatts a year without fast breeder reactors and with light water reactors alone, it would require a total of approximately 1.75 million tons of uranium by the year 2100 as indicated by line (b) in Figure 3.

In order to insure growth of 550,000 kilowatts per year with light water reactors alone, it would require a total of approximately 1.54 million tons of natural uranium by the year 2100. In order to maintain 92 million kilowatts with light water reactors alone, it would require a total of approximately 1.34 million tons of natural uranium by the year 2100.

If we were to illustrate this in Figure 1, it would mean that Japan would end up using the majority of known uranium resources in the free world by itself, which we have to admit would be impossible to secure.

(2) Fast Breeder Reactors Put Into Commercial Use From 2030 in Moderate Growth Scenario "Scenario 1"

Figure 11 is a graph showing that a growth rate which combines the power plant energy production of both light water reactors and fast breeder reactors in an FBR cycle with a 1.2 breeding ratio and three-year out-of-core cycle would be held to 550,000 kW rate of growth per year in a moderate growth period of demand. In the first few years after 2030, it would not be possible to use plutonium from reprocessing spent FBR fuel to put new FBRs into service because the initial fuel, after being removed, would still be in the process of being reprocessed and manufactured into fuel. The number of new fast breeder reactors being put into service would be increased after that, but there would still be a low rate of growth in overall nuclear power plant energy production because light water reactors would be decommissioned. After the year 2055 or so, it would be possible to insure adequate growth once again of 550,000 kilowatts a year from the standpoint that we would catch up the lost ground from decommissioning light water reactors.

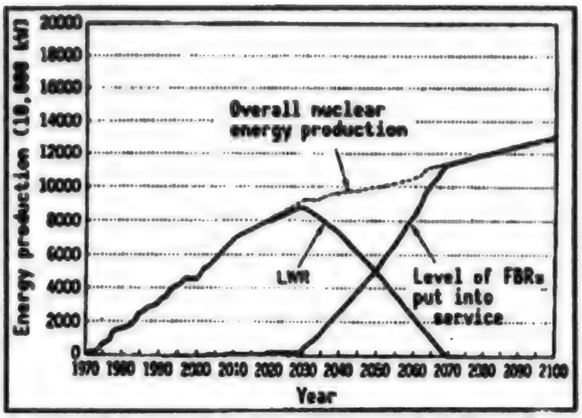

Figure 11. Scenario 1 (moderate growth, 1.2 breeding ratio, three-year out-of-core fuel cycle)

(3) Fast Breeder Reactors Put Into Commercial Use From 2030 in High Growth Scenario "Scenario 2"

Figure 12 is a graph showing that a growth rate which combines the energy production of both light water reactors and fast breeder reactors in an FBR cycle with a 1.2 breeding ratio and one-year out-of-core cycle would be held to 1.1 million kilowatt rate of growth per year in a high growth period of demand. In the first few years after 2030, the rate of growth of fast breeder reactor power plants would be between 1.9 and 2.3 million kilowatts per year, but there would still be a low rate of growth in the overall nuclear power plant energy production because there would be a reduction in power plants due to the decommissioning of light water reactors. After the year 2035 or so, it would be possible to insure adequate growth once again of 1.1 million kilowatts a year from the standpoint that we would finally make up the lost ground from decommissioning light water reactors.

(4) Delaying Introduction of Commercial Fast Breeder Reactors in Moderate Growth Scenario "Scenario 3"

A study was done on a scenario in which the introduction of commercial fast breeder reactors offered in Scenario 1 was delayed by 10 years and these were put into service starting in the year 2040 instead.

The first demonstration fast breeder reactor, a 660,000-kilowatt reactor, would be put into service in the year 2009. This would be followed by a second million-kilowatt reactor in 2020 and a third million-kilowatt reactor in 2030.

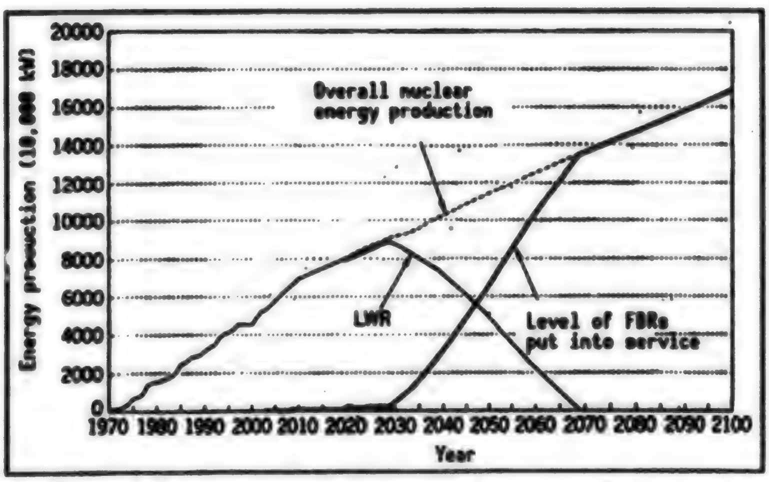

Figure 12. Scenario 2 (high growth, 1.2 breeding ratio, one-year out-of-core fuel cycle)

Even after the nuclear energy production of Japan had reached 92 million kW in the year 2030, we assumed that it would increase at the rate of 550,000 kilowatts a year until the year 2040 due to the new light water reactors being built. Assuming a reactor life of 40 years, light water reactors would continue operating until the year 2080. The average rate at which reactors would be decommissioned in the 40 years after 2040 would work out to about 2.3 million kilowatts per year.

The total amount of natural uranium needed for the light water reactor system would be about 770,000 tons. We would need approximately 110,000 tons more uranium due to the 10-year delay.

If we were to show the 700,000 tons of uranium needed after 1990 in Figure 1, it would show Japan using nearly 40 percent of the known uranium resources in the free world by itself. In order to secure this amount of uranium, it would require an exceptionally major effort on the part of Japan according to that scenario.

(5) Delaying Introduction of Commercial Fast Breeder Reactors in High Growth Scenario "Scenario 4"

A study was done on a scenario of delaying introduction of commercial fast breeder reactors offered in Scenario 2 by 10 years and having them put into service starting in the year 2040.

The first demonstration fast breeder reactor, a 660,000-kilowatt reactor, would to be put into service in the year 2009. This would be followed by a second million-kilowatt reactor in 2020 and a third million-kilowatt reactor in 2030.

Even after the nuclear energy production of Japan had reached 92 million kW in the year 2030, we assumed that it would increase at the same tempo of 1.1 million kilowatts a year until the year 2040 due to the new light water reactors being built. There would be no new light water reactors built after the year 2041. Assuming a reactor life of 40 years, light water reactors would continue operating until the year 2080. The average rate at which reactors are decommissioned in the 40 years after 2040 would work out to about 2.5 million kilowatts per year.

The total amount of natural uranium needed for the light water reactor system would be about 810,000 tons. We would need approximately 140,000 tons more uranium due to the 10-year delay.

If we were to show the 730,000 tons of uranium needed after 1990 in Figure 1, it would show Japan using nearly 40 percent of the known uranium resources in the free world by itself. In order to secure this amount of uranium, it would require an exceptionally major effort on the part of Japan according to that scenario.

(6) Speeding Up Entry of Fast Breeder Reactors "Scenario 5"

This scenario is not included in the long-term plan, but is one in which we looked at the possibility of rapid progress being made in developing the technologies to put commercial fast breeder reactors into use 10 years earlier than either the first or second scenarios, which would mean being put into service in 2020.

The first demonstration reactor, a 660,000-kilowatt reactor, would be put into service in 2009. There would be no new light water reactors built after 2021 in this scenario. Assuming a reactor life of 40 years, light water reactors would operate until the year 2060. The average rate at which reactors would be decommissioned in the 40 years after 2020 would work out to about 2.0 million kilowatts per year.

The total amount of natural uranium needed for the light water reactor system would be about 540,000 tons. We would need approximately 120,000 tons less uranium due to the 10-year acceleration.

(7) With 1.2 Breeding Ratio and Three-Year Out-of-Core Cycle in High Growth Scenario "Scenario 6"

In Figure 13, we show a sixth scenario which features a 1.2 breeding ratio and three-year out-of-core cycle in a high growth situation. In order to insure the growth of nuclear energy production, we would need to put enough light water reactors into service that give us a total of 20.2 million kilowatts after the year 2031. The total amount of natural uranium needed in this scenario would be approximately 770,000 tons.

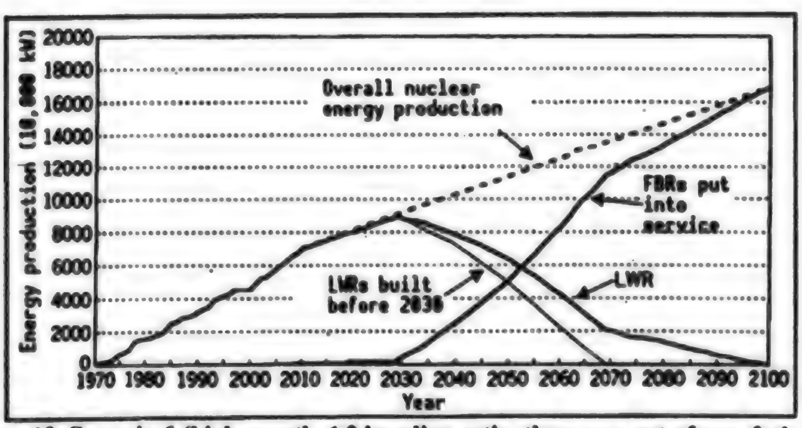

Figure 13. Scenario 6 (high growth, 1.2 breeding ratio, three-year out-of-core fuel cycle)

(8) Without FBR Reprocessing "Scenario 7"

In order to determine what the likely effect would be of putting fast breeder reactors into service from the year 2030 but putting off and delaying FBR reprocessing, we studied a scenario in which none of the FBR spent fuel was reprocessed.

It would mean that even if fast breeder reactors were put into service after the year 2030 using plutonium obtained entirely from light water reactors with no surplus that FBR energy production would rise to no more than 15 million kilowatts per year and that it would decline after that due to a shortfall in LWR spent fuel.

Finally, it would be senseless to put fast breeder reactors into service without fuel recycling, and if the implementation of fuel recycling were to fall significantly behind the introduction of fast breeder reactors, it would result in serious harm to the nuclear energy supply.

9. Other Areas of Study

(1) Plutonium Supply and Demand Balance

Figure 14 shows the balance of plutonium supply and demand after the year 2030. It took into account the lead time required to manufacture fuel and assumed a plutonium demand that was created two years prior to loading in the reactor. Supply included the plutonium located abroad and the plutonium produced by overseas reprocessing. A balance is achieved by demand from research and development and Pu-thermal reactors, leaving no surplus plutonium.

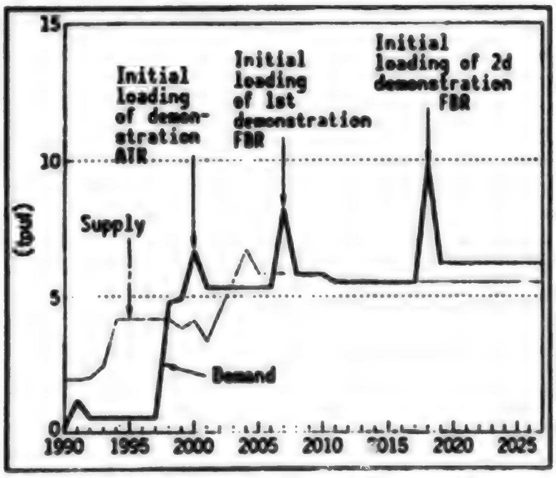

Figure 14. Plutonium Supply and Demand Balance

The plutonium supplied in 2027 shown on the right edge of the horizontal axis is loaded into the reactor in 2029.

After the year 2030, there will be no surplus plutonium because fast breeder reactors will be put into service in a way as to prevent a surplus or a shortfall of plutonium.

(2) Plutonium Committed to FBR System From External Sources and Plutonium 1

Figure 15 shows the changes in the amount of plutonium obtained from reprocessing LWR uranium fuel and reprocessing MOX fuel presented in the first scenario and committed to the FBR system, and the changes in the amount of plutonium obtained from FBR fuel reprocessing. The level of FBR spent fuel reprocessing around the year 2050 will be about 500 metallic tons a year.

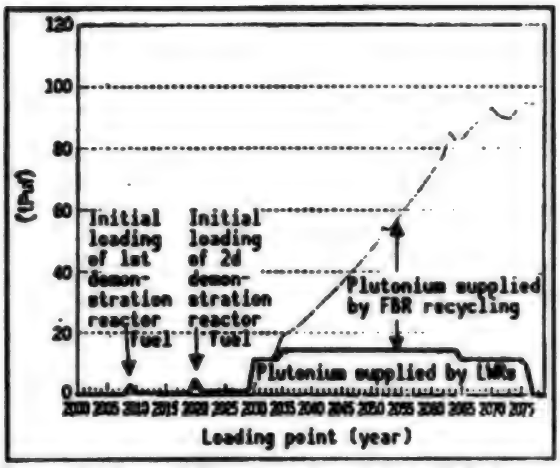

Figure 15. Annual Plutonium Supplied to FBR System

The total amount of plutonium obtained from FBR spent fuel reprocessing plants between 2030-2069 when fast breeder reactors and light water reactors will be operating concurrently will be 1390 tPUF, or 2.6 times the total amount of plutonium that the FBR system will be getting from LWR spent fuel reprocessing plants and Pu-thermal spent fuel reprocessing plants during the same period, which will be 540 tPuf, reserving for FBR spent fuel reprocessing plants an important place in terms of supplying raw material.

(3) LWR Spent Fuel Reprocessing Plants

We also did a study on a scenario in which the LWR spent fuel reprocessing plants which supply plutonium to the FBR system increase the amount of spent fuel they reprocess by 1.25 times, or from 1600 tons a year to 2000 tons a year. It did not have any effect on the total plutonium supply, but it did increase the amount of fast breeder reactors being put into service by causing the initial supply to increase. When we compared how many fast breeder reactors with a 1.2 breeding ratio and three-year out-of-cycle time could be put into service by 2050 in the event they started in 1930, we found that the 2000 tons per year enabled 1.2 times more fast breeder reactors to be put into service.

10. Conclusion

If fast breeder reactors are never put into service, Japan will need 1.75 million tons of natural uranium by the year 2100, and will by itself monopolize the majority of known uranium resources in the free world today. From that, we can see that the use of fast breeder reactors is indispensable to Japan. The timing of putting fast breeder reactors into service will be determined by future trends in uranium supply and demand, but when we consider that Japan will need 660,000 tons of uranium and must secure almost 30 percent of the known uranium resources in the free world should it decide to start putting fast breeder reactors into service in the year 2030, it should start moving forward quickly to develop the technologies that will enable it to put fast breeder reactors into service by around the year 2030.

It should also move ahead with plans to develop the technologies so that fast breeder reactors can be placed in service at the rate of two reactors a year starting in the year 2030, and gradually increase that to three reactors a year.

Concerning the characteristics of the reactor and fuel cycle, Japan should also continue doing R&D on the breeding ratio and fuel cycle, building upon the R&D done to achieve the 1.2 breeding ratio and three-year out-of-core fuel cycle, and see if it can achieve an even better breeding ratio and out-of-core fuel cycle so that fast breeder reactors are better able to deal with large increases in demand.

In order to facilitate the process of putting fast breeder reactors into service, concrete studies must be done in order to determine how development should proceed until the year 2030. In other words, studies are needed to coordinate a development scenario involving fast reactors and a fast reactor fuel cycle and a Pu-thermal reactor scenario as well. The specific items to be studied include a post plan for a second reprocessing plant, development phases of FBR reprocessing, a storage scenario for spent fuel, scale of MOX fuel manufacturing, and storage of vitrified waste. Japan should take an aggressive stance in particular with regard to LWR spent fuel reprocessing plants and move forward with R&D to revolutionize the technologies used in those plants. These will be the plants that will supply the plutonium required by fast breeder reactors and which will occupy an extremely important position in the future.

By making thoroughgoing preparations as described above, Japan will be able to put fast breeder reactors into service in a system that pays strict attention to nuclear nonproliferation by not producing any excess plutonium after the year 2030 and serves the supply of nuclear energy.

STA's Superconductivity Material R&D Promotion Committee Builds New Database for Superconductivity Research

95FE0100 Tokyo NIKKAN KOGYO SHIMBUN in Japanese 24 Nov 94 p 1

[FBIS Translated Text] The superconductivity material R&D promotion committee (Chairperson: Professor Ryozo Aoki, Osaka University) of the Science and Technology Agency has constructed a database suitable for superconductivity material R&D. It was tedious and difficult to use the existing database, primarily the "literature database," in which many data were given without standardized conditions for measurements and evaluations.

The newly developed database, a prototype, defines terminologies such as critical temperature, critical magnetic field, and critical current; describes measurement methods thereof; and clearly explains the preparation and processing methods for samples. The committee has begun preparing to distribute the database on floppy disks and compact disks to those who want it.

Since the discovery of oxide-based high-Tc superconductors, it has become necessary for the superconductivity data to include data concerning critical magnetic fields, critical currents, and superconductivity electron states, which were not needed for metallic superconductors. Furthermore, newly discovered superconductors are expected to be used widely in such fields as magnetic materials and compound semiconductors, so that it has also become necessary to add new data and the kinds of data that researchers in other fields can use beneficially.

Even though individual researchers each appear to have compiled an enormous amount of research data, their measurement conditions and evaluation standards have been so arbitrary that researchers have not been able to compare their own data with others' data. Under these circumstances, researchers are said to have had to waste much time and labor to carry out R&D.

Thus, the committee built a new database that would be useful for future research. The committee first developed a system for establishing and clearly identifying each datum and for classifying and recording data obtained by basic studies. The database also permits users to retrieve any graphs and photographic information. In addition, with the new database, it is also possible to retrieve newly discovered analytical properties and information.

Chairperson Aoki says this: "We can retrieve new characteristics and information regarding superconductive materials by using a key word. We can also add data that will become important in the future, and it is possible for one to establish the direction of this research."

The committee hopes to eventually make this database freely accessible to any researcher worldwide by connecting it with an "inter-ministerial network" that will allow information exchange across the barriers of government ministries and agencies.

NTT To Conduct Multimedia Experiment Using PHS

95FE0236A Tokyo NIKKAN KOGYO SHIMBUN in Japanese 23 Jan 95 p 11

[FBIS Translated Text]

Beginning in May, Nippon Telegraph and Telephone (NTT, President Jin Kojima) will conduct multimedia experiments using the Personal Handy Phone System (PHS). NTT is aiming at the possibility of data communication which includes video. Through these application tests which use multimedia terminals that are movable, PHS is being considered due to such things as transmission capacity and speed, and the major role of multimedia mobile communication. Practical uses for multimedia service, such as data communication, are gaining momentum.

Exploring the Possibility of Data Communications

The experiment is called "Personal Multimedia Communication (PMC) Experiment Plan" and is scheduled to be conducted for approximately one year at the Musashino Communications Network Laboratory.

First, the transmission capacity of the PHS will be fully utilized. Then, such things as the practical usage of data transmission of image and character information not including voice, will be measured.

PHS is a digital system. Furthermore, it has a data transmission speed of information of 32 kilobits per second which is the largest capacity among mobile communication devices including the portable car phones already in use.

When compared with portable car phones, it cannot be used during high speed movement. However, it has the advantage point of having small power consumption and appears to be most suited for multimedia mobile communications.

Service is planned to start in July beginning with the metropolitan Tokyo area. With these experiments, the possibilities of application of multimedia should increase and spur on the development of the portable information terminal.

MITI To Strengthen Security Measures to Cope With Larger Information Networks

95FE0236B Tokyo NIKKAN KOGYO SHIMBUN in Japanese 21 Jan 95 p 2

[FBIS Translated Text]

Full Scale Research Beginning Next Year To Improve Encoding Technology

With the expansion of international computer networks, in order to strengthen the security measures for business transactions and the exchange of highly classified information, in 1995, the Ministry of International Trade and Industry will embark in full scale research into strengthening authorization technology, basic maintenance to promote use, and a public access control system and standardization. Also, with an examination of the current computer system safety countermeasures and as a privacy protection measure, MITI plans on using the guidelines for strengthening public guidelines.

In November 1994, the Ministry of International Trade and Industry established an investigative committee to look into the problems of security and privacy (private investigative organizations working for the machine information industry bureau chief, Chairman Showa Uzawa, Honorary Professor at Aoyama University). Five operating groups such as privacy, security, and authorization were examined, and in the middle of January, preliminary information was collected.

According to the information collected, because the present countermeasure standards for hackers and computer viruses do not have the end user as the main focus, MITI is examining rewriting the standards, reviewing virus damage reports, promoting research and development of virus analysis programs and international cooperative research, and dealing with criminal cases of illegal access.

A related technology with similar problems of encoding and authorization, is information system security, the maintenance of which is an important means of promoting a highly technical, user friendly environment. A system coordination is necessary for utilization of encoding and authorization technology for communication between two countries.

In concrete terms, functions for encoding and authorization are being developed and strengthened, information on the cost, etc. is being offered to the user, a public access record and control system is being created, encoding is being standardized, and international rules are being promoted. The Ministry of International Trade and Industry states the need for a public access control system in order for the other party to easily use the contents of the transaction when signals are encoded.

In the privacy protection area, with developments in end user computing, the problem of personal information leaks is increasing. Due to this increase, a strengthening of existing guidelines needs to occur in the area of personal information, as has been demonstrated in the public sector. Areas to be developed are preparation of voluntary guidelines, registration, specific control systems for individual companies, establishment of a code of ethics, access control, and development of tamper proofing measures. MITI also states there is a need for a review of measures to maintain safety of existing computer systems, and has given direction on security evaluation standards and adoption of authorization control systems. MITI started dealing with these directives beginning in 1995 and plans to examine concrete countermeasures.

Fujitsu, Nissho Iwai Complete Optical Transmission Trunk Line Between Beijing and Harbin

95FE0236C Tokyo NIKKAN KOGYO SHIMBUN in Japanese 19 Jan 95 p 5

[FBIS Translated Text]

Two Routes in Operation

[Beijing Branch Office] Fujitsu and Nissho Iwai have completed, without delay in construction, an optical transmission trunk line between Beijing and Harbin. It is the longest project in China to be manufactured by an independent manufacturer. At 2:30 pm on the 18th in Beijing, a number of persons connected with the project from both Japan and China were in attendance as the line was formally opened for operation.

Communication infrastructure is the most important project being promoted by the Chinese government. The Beijing-Harbin Optical Transmission Trunk Line was built without delay with the cooperation of China's Ministry of Postal Communications with a signed contract from February, 1993, to April, 1994, with third party loans.

This large scale optical transmission trunk line which directly connects multiple provinces is composed of two routes, the Eastern route which was signed in December 1993 (Beijing-Tianjing-Shenyang-Changchun-Harbin-Shenyang-Dalian) and is 2,400 kilometers (¥900 million) and the Western route which was signed in April 1994 (Beijing-Chengde-Tongliao-Baicheng-Chichiharu-Harbin) and is 2,600 kilometers (¥500 million).

Nationally owned businesses, which have come to the end of a business slump, are combining efforts and the impact of achieving the communication infrastructure in northeastern China is large. A large contribution is expected as well on the project speed of the progress of the country's principle market economy, the maintenance of the distribution route, and the development of Douman Jiang (Tumen Jiang).

Oki Electric To Develop Single Chip Main Signal Processing for PHS

95FE0236D Tokyo NIKKEI SANGYO SHIMBUN in Japanese 17 Jan 95 p 5

[FBIS Translated Text]

During 1996, Oki Electric will integrate the main signal processing function of the PHS (Personal Handy Phone System - a simple portable phone) into one LSI (Large Scale Integration Circuit) and consolidate it into a single chip. The compression function of the voice signal and the modem function which transmits the signal externally, have been miniaturized to one LSI circuit. Furthermore, during 1996, multiple data functions which transmit many signals on the same frequency band, and the processor for signal processing will be combined. By doing this, Oki Electric is aiming for a production cost reduction of the PHS.

First, these two functions which have been combined make up the QPSK Modem which aligns the AD.PCM coding and the timing which compress the human voice at a speed of 32 kilobits per second. The QPSK Modem then transmits the voice data on the frequency band for the PHS. The circuit is not usually in operation, but when necessary a portion of the circuit operates, and thus a low voltage drive of 3V is possible.

As a result, when converting an analog signal to a digital signal, noise which has a tendency to occur is suppressed to the smallest limit. The size of the trial production chip is 5mm square with a machining precision of 1.2 microns (1 micron is 1/1000 of a millimeter).

The integration of the multiplex LSI which is the main circuit of the PHS will be focused on during 1995. The processor which controls three LSI circuits will also be focused on in 1995. Finally, the functions which have been on four chips will be consolidated on one LSI chip.

The multiplex LSI is an LSI characteristic of the PHS which uses the same frequency radio wave for both sending and receiving signals. When this is made into one chip, it is made to accommodate the development of multimedia devices which use the PHS transmission frequency band.

NTT DoCoMo Joins Data Mobile Communications Using Packet Exchange Method

95FE0236E Tokyo NIKKAN KOGYO SHIMBUN in Japanese 17 Jan 95 p 1

[FBIS Translated Text]

According to related sources, NTT Mobile Communications Network (NTT DoCoMo, President Koichi Oboshi) will introduce a packet exchange to the digital portable car phone system. This establishes their intent to enter the data mobile communications market. Experiments are set to begin within the year. During 1996, it will begin to be used and expanded throughout the entire country. Data mobile communications have been used by Japan City Media (JCM) since 1989, and Europe and America have followed suit. The Packet Exchange Method for digital portable car phone systems is the first of its kind in the world. Also, the world's fastest transmission speed in mobile communications has been realized. It appears the same service will lead to multimedia mobile communications. However, NTT DoCoMo, the leading manufacturer, embarking in this same field with this new method is likely to fuel the market fire for distribution.

NTT DoCoMo, a newcomer in the arena, has developed the world's first data mobile communication system standard called the Digital Cellular Packet (DCP). Practical application is its major point. As a result, the three

channels of the present portable car phone have been made into one. With 42 kilobits per second, it is expected to be the fastest transmission speed in mobile communications. Furthermore, it can be used in existing systems as is and with modifications to parts of the software and switchboard, the service area can easily be enlarged to span the entire country.

The exclusive service of data mobile communications uses a portable information terminal, and at any time or any place, data and images can be sent in both directions. Furthermore, as exclusive service, with the packet exchange there, systems such as portable car phones which are based on using voice can have very high speed, high quality data communication. In America, signs of wide-spread use can be seen with mobile computing, e-mail exchange in businesses, etc.

However, JCM's Teleterminal, the world's first, can only be used in a portion of the Tokyo metropolitan area, and the transmission speed is limited to 9.6 kilobytes per second. On the other hand, worldwide, America's Motorola Corp. has followed in succession with the "Data Tac" method (transmission speed of 19.2 kilobits per second), while Sweden's Erickson Corp. has followed with its "Mobitechs" method (same 8 kilobits). Thus the intensity of the dispute over a worldwide standard (Defacto Standard) is increasing. Taking only this into consideration, the participation of NTT DoCoMo with a new method should have a substantial impact.

TWJ To Start Cell and Frame Relays Through ATM Networks

95FE0236F Tokyo NIKKAN KOGYO SHIMBUN in Japanese 18 Jan 95 p 11

[FBIS Translated Text]

Nihon Kosoku Tsushin (TWJ, President Kan Higashi) is aiming at introducing an asynchronous transmission mode (ATM) exchange machine from America's AT&T and Hitatchi Manufacturing in April and will thus embark in cell and frame (FR) relay service through next generation communication ATM networks. ATM exchange machines are set up in three network centers, Tokyo, Osaka, and Nagoya. Testing on the new service will begin in April with full scale service starting this fall. This is the first time new NTT will begin network service through ATM technology. By being first with service which uses next generation network ATM technology, they are striving for expansion of the communication business.

The ATM machine which TWJ is introducing includes three of AT&T's newest "Globe View 2000" and four of Hitachi's HA600PA. By March, TWJ plans on completing construction of network covering the entire country through optic fibers which are constructed along the main expressways. In this network, AT&T manufactured ATM machines will be connected, and as access system exchange machines, will be joined with Hitachi manufactured machines, and the next generation ATM communication network will be constructed.

Nippon Telegraph and Telephone (NTT) is the first to combine network service through ATM machines with the simultaneous transmission mode (STM). But at new NTT, TWJ is the first long distance system. The lateness of TWJ's service through a network spanning the entire country has had a great effect and as a result, put a damper on DDI and Japan Telecom. By being first with the next generation ATM network, competition will be promoted.

Nichimen Gets Order to Install Eurasia Optical Communication Networks

95FE0237A Tokyo NIHON KEIZAI SHIMBUN in Japanese 17 Jan 95 p 1

[FBIS Translated Text]

NTT International in Turkmenistan

With the cooperation of NTT International (Tokyo, Hojima), an international business subsidiary of Nippon Telegraph and Telephone (NTT), Nichimen has received the order to install a portion of an optical fiber network which crosses the continent of Eurasia. The portion is the central Asia and Turkmenistan area and is for approximately ¥10 billion. The plan calls for 11 countries in Europe to cooperate in constructing an optical fiber communications network from China to Germany. The goal of completion is by the latter half of 1996, but the commencement of construction has been delayed. This is due partially to the decision to privatize in anticipation of concrete plans, inspired by the economic development of Central Asia.

Nichimen will provide the financing and the equipment, and will supervise the construction. NTT International will act as an engineering consultant. Construction will begin this fall. A 967-kilometer cable will be constructed in Turkmenistan following from Uzbekistan and the communications networks will be connected in Iran. To prepare for any cable problems, the microwave wireless networks of the participating countries will be changed from analog to digital. Completions are scheduled for the latter half of 1996.

The plan for a communications network spanning the Eurasia continent calls for the construction of an optical fiber going from Shanghai, China, to Frankfurt, Germany, for a total length of 17,000 kilometers. The aim is for the maintenance of a communications infrastructure with central Asia as the center. The countries which will be passed through include Kazakstan, Turkmenistan, etc., and the five countries of Central Asia, Iran, Turkey, Ukraine, Poland. It appears that the total investment will exceed ¥100 billion.

If the plan is realized, communication from Japan to the countries in Central Asia will simplified. It is also anticipated that businesses will take the opportunity to expan[illegible] regions of Central Asia which have underground resources such as oil.

MITI, Major Consumer Electronics Companies Agree to Jointly Develop Multimedia Core System Technology

95FE0237B Tokyo NIHON KEIZAI SHIMBUN in Japanese 14 Jan 95 p 1

[FBIS Translated Text]

Computer and Consumer Electronics To Be United

Seven leading manufacturers of information and consumer electronics which represent Japan including NEC, Matsushita Electronics Manufacturing, Sony, ASCI, etc., in cooperation with the Ministry of International Trade and Industry (MITI), have agreed to jointly develop multimedia core system technology. A new company will be established at the end of March. Combined connective technologies, etc. will be developed for computers and consumer electronics when using high definition television (HDTV) and freely exchanging images, etc. between families and businesses. In the industrial world, research and development in this area has just begun. However, it has been determined that there are limitations to independent development by independent businesses. In contrast to America, which has proceeded with the multimedia field for next generation communications, the leading high-tech manufacturers of Japan and MITI have merged together in this effort.

The new company's name is "Digital Vision Laboratories" (temporary name). Those participating include NEC, Sony, Matsushita, ASCI, Toshiba, Fujitsu, and Hitachi Manufacturing. The capital is ¥6 billion. The Fundamental Technology Research Promotion Center, an auxiliary organization of MITI, received capital from industrial special investment accounts. Of these investment accounts, 70 percent is from investments and the remaining 30 percent is from equal shares of the seven companies. In March, an establishment committee will meet with the goal of establishing the company by the end of March. Initially, the company will have forty to fifty employees.

The object is software technology called Middle Wear. Connection standards and communications software will be developed for connecting CATV (cable television) and computers and for enjoying television service in both directions on the household television. The realization of this is anticipated before the year 2000.

The independent development in businesses of the technology necessary for businesses and families to receive multimedia service is limited. Not only can one company not develop all the devices, but the mutual cooperation of various technologies from consumer electronics and computers, to communication and broadcasting is necessary. With Japan's leading manufacturers of consumer electronics and computers as the core of this new company, the basic technology and the standards will be developed for this newest product which is a union of computer and consumer electronics.

In the multimedia field of next generation communication, when compared with America which has a colorful group of newly established companies such as Microsoft, Japan is lagging behind. Worldwide, America is so strong that it has set the standards for basic computer software, databases, and terminals, and thus many companies have been established. However, their technology for using digital HDTV, etc. is not complete. Thus, for Japan to come from behind, MITI and the major consumer electronics companies have decided to cooperate in developing the basic technology.

Obstacles In Industry are Dissolving

The background for MITI and businesses cooperating together for development was because of a sense of crisis that when compared with America, Japan cannot compare in information system technology, software competition and strength of development. (Machine Information Industry Bureau) MITI's plan for the company, which was established in November of last year, is to lend aid to programs dealing with highly technical information.

The reason for the rehabilitation of the American industries during the 1990s was that venture businesses which specialized in basic software, semiconductors, etc. experienced a sudden rise in strength. Businesses which were represented by companies such as Intel and Oracle saw much success in specialized fields, and by cooperating together, began to see new growth.

On the other hand, in Japan, computer manufacturers have been spoiled by the status of borrowing standards which were used by the newly established American companies. Thus the danger in their present condition was to be relegated with only low added value manufacturing which was firmly rooted in Japan's high tech manufacturers and MITI.

To grapple seriously with the next generation of multimedia, in order to connect and utilize the various forms such as CATV (cable television), satellite broadcasting, and computer networks, the networks surrounding the industrial world for computers, consumer electronics, communications, and broadcasting, barriers had to disappear. Thus this new company must break new ground at removing barriers and, from an intermediate viewpoint, will attempt to turn the table to compete with American companies.

Sumitomo Electric Develops H-PCF Optical Connector and Module for Medium and Short Distance Communications

95FE0237C Tokyo NIKKEI SANGYO SHIMBUN in Japanese 5 Jan 95 p 1

[FBIS Translated Text]

Sumitomo Electric has developed a hard plastic clad fiber (H-PCF) exclusive optical connector and optical module for medium and short distance communications and has begun shipment of samples. The H-PCF allows high speed communication of 125 megabits per second. The amount of usage in OA.FA (office and factory automation) is increasing. However, in order to substitute connectors and modules for long distance fibers, much time was needed for connection. With the exclusive connector and module, the time needed for connection is three minutes, about one fourth the present time required. The terminal execution time has been reduced over a large range.

Other than use in office and factory automation, recently attention has been given to H-PCF as a communication infrastructure in multimedia which is connected from optical fiber trunk lines to households. Compared with long distance optical fibers, when using a module and connector for long distance optical fibers in the H-PCF which has a large aperture, there was the problem that execution time increased and the amount of information which could be transmitted decreased.

By joining the newly developed connector and module with the H-PCF, it can support the equivalent amount of information transmission as the all glass fiber. Also, because the glue and the polishing are not needed at the terminal connection, the localized execution time was reduced greatly to three to five minutes.

The H-PCF is mainly used in factory and office LAN (Local Area Networks) as communication infrastructure for medium and short distances up to 500 meters. It appears that the amount that it will be used as a communication infrastructure to connect from optical fiber trunk lines to households for image digital transmission and optical switchboards will quickly increase.

NTT, DDI To Conduct PHS Experiments in China

95FE0237D Tokyo NIKKAN KOGYO SHIMBUN in Japanese 7 Jan 95 pp 1,5

[FBIS Translated Text]

NTT and DDI and the communication device manufacturers, NEC and Matsushita Communications Industry, will work together to conduct experiments on the Personal Handy Phone System (PHS) in China. Experiments are set to begin at the earliest in April in cooperation with China's Ministry of Postal Communications. This will be the first experiment on PHS in China. The goal is to standardize PHS in China with the Japanese market. The experiments will provide the foothold for the acceleration of the introduction of PHS in China. European and American businesses and communication device manufacturers are aiming at selling competitive systems to the PHS in China. According to the Chinese Ministry of Postal Communications, the companies are getting a feeling for the market with the experiments, and the leadership struggle between Japanese, European, and American companies for the introduction of next generation portable phone systems will become intense.

Standardization To Begin In April As Well

The PHS system is much cheaper than the present portable phones in terms of the cost of telephone calls and the cost of the telephone itself. The PHS system was developed independently in Japan. Systems which compete with the PHS include the European "DECT" system and the American PCS.

The reason for beginning experiments in China with the five leading manufacturers in Japan acting in an alliance was that it was determined that if the companies independently conducted experiments, the standardization and sales of Japan's PHS would be delayed. Thus it was decided to form a merger and work in cooperation. The Radio System Development Center (RCR), an auxiliary organization of the Ministry of Postal Services, which promotes the standardization of radio wave usage, will hold a PHS seminar in China in February or March. After the alliance of the five companies has implemented the seminar, they will join with the Ministry of Postal Communications and begin experiments in Beijing, etc. in April or May.

Presently, the frequency for the wireless portion of the PHS experiments is the same as in Japan, 1.9 gigahertz. Also, the wired portion of the experiments uses an integrated digital communication network (ISDN), and the radio base station is connected through an interface for the PHS.

China is aiming at an expansion of the switchboard terminal base of 114 million by the year 2000. In the future, it appears that Asia will experience such rapid growth that it will become the largest communications market. Analog portable phones are also showing high annual growth of 40-50 percent. It is estimated that by the latter half of 1994, they will have grown to approximately 1 million phones.

Also, it has been decided that Japan's PHS system will be used in Hong Kong. NTT and Hong Kong Telecom began PHS experiments in the latter half of 1994.

If experiments are started in China as well, it will provide great progress for the standardization of PHS in the Asia market. As a result, it is possible that for the first time in the communications field, high tech products using the Japanese method could lead the market worldwide.

NEC To Begin With Southeast Asia

NEC (President Hisashi Kaneko) plans to expand its overseas business of its Personal Handy Phone System (PHS). For the first time overseas, the Chinese have decided to use a Japanese communication system at Hong Kong. This is due to the rapid growth of the introduction of the PHS system with Southeast Asia as the center. The Ministry of Postal Services as well is backing the overseas expansion of the PHS system. NEC, in particular, has seen a resuscitation of its actual results from delivery of switchboards in Indonesia, Malaysia, Thailand, etc. and in the same region, sales have accelerated. Also, in South America, experimental PHS demonstrations are being conducted in Chile. NEC is planning for business expansion in a literal worldwide market. The overseas expansion of PHS is greatly inspired by NEC, Japan's leading communications manufacturer, concentrating earnestly on its overseas expansion of PHS.

The PHS is a digital cordless phone which can be used both inside and outside. It appears to be the favorite in future personal communications. In Japan, actual use is scheduled to begin in July 1995. It is estimated that 30 million units will be in use by the 21st century. Also, overseas, it has been decided that PHS will be introduced at Hong Kong. Even in countries where the expansion of the use of telephones has been slow, compared to phones which use wires, construction of the system is easy. The need for an effective mobile communication system and increased speed in maintaining a phone infrastructure is strong.

On the other hand, the Radio System Development Center (RCR) which determined the PHS standards, received support from the Ministry of Postal Services and in December, 1994, held seminars about PHS in Singapore, Malaysia, and Indonesia, in that order. Early this year, the same seminar will by held in Guangdong, China, the Philippines, and Vietnam. The possibility of introducing the PHS system in these areas in increasing.

By doing this, NEC, which has the accumulation of cooperative development of a system by Nippon Telegraph and Telephone (NTT), etc. has decided to earnestly embark in the expansion of the overseas market for the PHS system. By connecting and actually utilizing the PHS, and connecting with the major switchboards, NEC holds approximately half of the shares and should cut deep into the Southeast Asia communications business. It was determined that this strength would link to the business.

NTT Develops High Speed ATM Connectionless Module

95FE0237E Tokyo NIKKAN KOGYO SHIMBUN in Japanese 9 Dec 94 p 7

[FBIS Translated Text]

A High Speed of 2.4 Gigabits

Nippon Telegraph and Telephone (NTT, President Jin Kajima) announced on the December 8 that it has developed an Asynchronous Transmission Mode (ATM) connectionless module which has a speed of 2.4 gigabits per second which is one unit faster than the present module. Connectionless communication which did not require spreading a connection before hand between users was concentrated on as a practical application method for network resources. Now, by allowing for high speed, the construction of a virtual LAN environment which has either network and LAN which is connected to the ATM network or one LAN, is possible.

The module which was developed is installed inside the ATM network. Data sent from the LAN which is connected to the ATM is concentrated in an ATM connectionless server which controls traffic for each path.

Careful consideration was given to the structure of members in an admission area and to the flexibility of the processing capacity. A maximum of four ATM connectionless servers, which have a data transmission speed of 600 megabits per second, can be loaded. As a result, the processing speed is one digit faster than the present, and a virtual LAN environment is made possible.

The connection delay time with the desired party is done within tens of milliseconds and communication can be freely done. In addition to this, packed unit data designational control and simultaneous copy transmission for multiple users are possible. By constructing a virtual LAN environment, these types of functions are realized.

Connectionless communication is a method which follows the address information contained at the front of the data and, while searching for the lead of the communication, transmits data. In computer communications which require the existing connection, it is necessary to connect the terminal and the host computer coupled, and effective utilization of the network resources is difficult. However, when virtual LAN is made possible, the network resources can be effectively utilized.

Multimedia Time Division Multiplexer

95FE0321A Tokyo NATIONAL TECHNICAL REPORT in Japanese Dec 94 pp 41-48

[Article by H. Hakkaku, S. Fumuro, T. Kito, Y. Hanafuchi, H. Hamakochi, and W. Araya, Matsushita Communication Industrial Co, Ltd, Radio Communications Div]

[FBIS Translated Text] A multimedia time-division multiplexer (TDM) is the equipment which accommodates and multiplexes multimedia such as voice, data, etc., and transmits that media efficiently via high-speed digital circuits or other transmission services using common carriers. The AD-8600 series has been developed mainly for the 16kilobit and 8kilobit per second CODEC systems which can transmit G3 facsimile signals, for advanced flexible communication functions using INS net services, and for integrated management of the TDM network by NMS. In order to meet the increasing demand for LAN-to-LAN connection, a frame relay interface and LAN interface function have also been developed.

1. Introduction

In the past few years, as companies have seen their bases of production and business become more decentralized, there has been a growing demand, on the one hand, for wide area networks (WAN) to help companies deal with internal communications, and, on the other hand, for applications in which distance is not a problem for users. Accordingly, there has been a growing need to make the network system itself more economical, reliable, and faster than ever before. In that regard, the time division multiplexer (TDM) becomes an important tool. It is equipment which is able to multiplex information of various media such as audio, facsimile, and data into time divisions and transmit that information economically and centrally via high-speed digital circuits (SD circuits) or transmission lines, such as INS networks. In Figure 1, we show the configuration of a typical private corporate communication network.

On account of the increasing volume of information being transmitted, however, there has been a growing demand for lower circuit costs, particularly through the use of compression technology to lower the bit rate for transmitting audio signals without any loss of transmission quality. In addition, there has been a need to try to prevent problems arising with the transmission line and time division multiplexer itself, by minimizing the areas affected by means of redundant configurations and centralizing management of the network so that network managers can be quickly informed of the operating status of the system. A frame relay service, in the meantime,

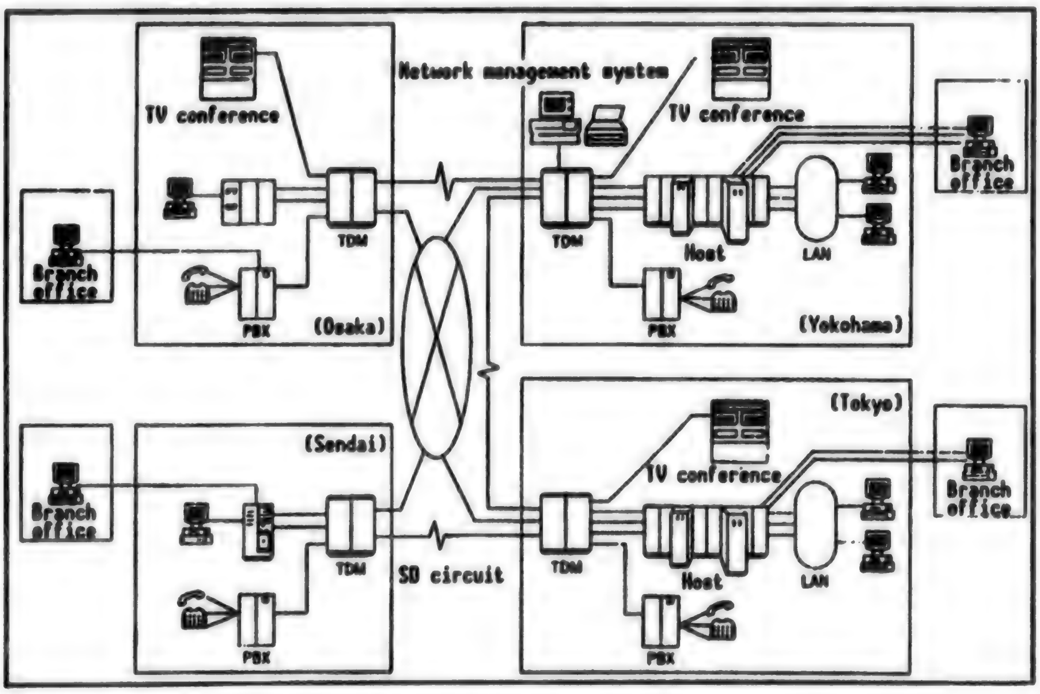

Figure 1. Configuration of Typical Private Corporate Communication Network

which has a high-speed data transmission capability and is expected to provide better multiplexing by frame multiplexing than time division multiplexing, offers the advantage of lower transmission costs and more effective use of equipment for users also using time division multiplexers. As we have alluded to above, the qualities that are essential to a time division multiplexer include efficient multiplexing, improved telecommunications quality, high reliability of the network system, and accommodation of a frame relay function. In this paper, we summarize the basic configuration and functions of the new AD-8600 series time division multiplexer that was developed to satisfy these conditions, and describe the main element technologies and future development of the time division multiplexer.

2. Basic Configuration and Main Features of Time Division Multiplexer

The AD-8600 series consists of three time division multiplexers, which vary according to the size of the network in which they are operating. It also consists of a network management system (NMS) that maintains centralized supervisory control of these TDM networks.

The package, which was designed based on the concept of an integrated system, can be used in series and is capable of dealing flexibly and economically with ever-expanding networks. In Table 1, we list the main specifications of AD-8600 series time division multiplexers developed by Matsushita Communication, and in Fig. 2, we show a block diagram of the multiplexer.

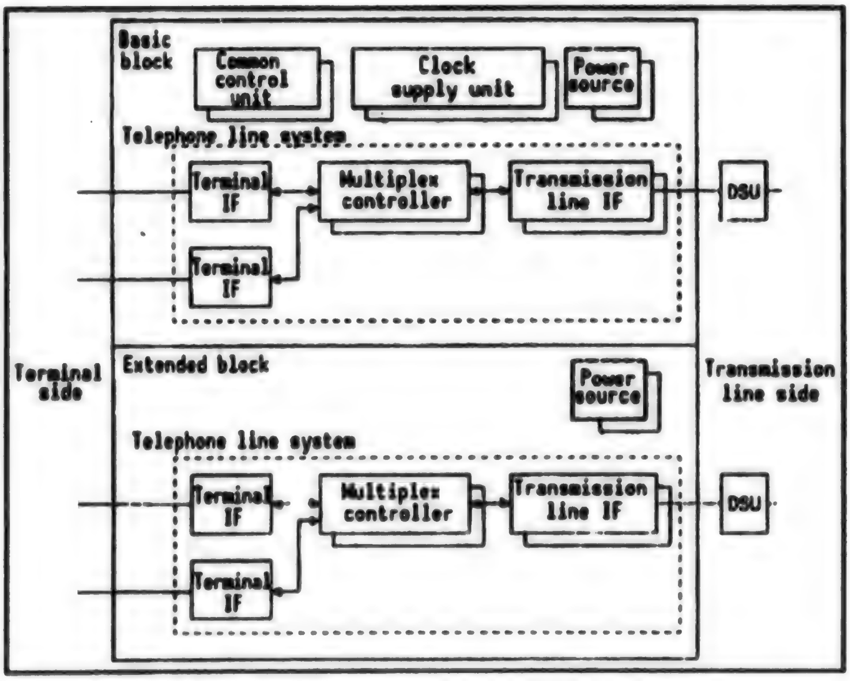

Fig 2. Block Configuration of Time Division Multiplexer

Table 1. Specifications of AD-8600 Series Multimedia Time-Division Multiplexers

Model	AD-8601	AD-8603	AD-8604
	Large	Small	Desktop
Transmission line interfaces	INS net 64 circuits, INS net 1500 circuits Y interface high-speed digital leased circuits (80 kbit/sec, 1.5 Mbit/sec, 6 Mbit/sec* I interface high-speed digital leased circuits (192 kbit/sec, 1.5 Mbit/sec, 6 Mbit/sec) TTC-specified 2 Mbit/sec private branch circuits		
No. of transmission circuits accommodated	Maximum 32 ports		Maximum 8 ports
Communication configuration	Point-to-point, multipoint, multidrop (Y interface), multiaccess (I interface)		
Synchronization method	Subordinate synchronization to transmission line		
Multiplexing system	Time-division multiplexing		
Transmission capacity	Maximum 16 Mbit/sec		Maximum 8 Mbit/sec
Accommodated terminal interfaces	Analog audio interfaces 2W/4W+SS/SR (audio speed: 64 kbit/sec, 32 kbit/sec, 16 kbit/sec, 8 kbit/sec) Digital audio interfaces TTC-specified 2 Mbit/sec interface, G.703-specified 64 kbit/sec interfaces (audio speed: 64 kbit/sec, 32 kbit/sec, 16 kbit/sec, 8 kbit/sec) Low-speed data interfaces V.24 (RS-232D), X.20, X.21 transmission speed: less than 19.2 kbit/sec or X.20 transmission speed: less than 1.2 kbit/sec High-speed data interfaces X.21, V.35, V.36 (RS-449) transmission speed: 48 kbit/sec, 56 kbit/sec 64, kbit/sec x n (n = 1,2,3,4,6,8,12,16,24,32*) High-speed digital leased circuit user network interfaces) Y interfaces (80 kbit/sec, 1.5 Mbit/sec, 6 Mbit/sec) I interfaces (192 kbit/sec, 1.5 Mbit/sec, 6 Mbit/sec) Frame relay interface LAN interface		
Audio compression system	32 kbit/sec: ADPCM G3FAX communicability (9.6 kbit/sec) 16 kbit/sec: LD-CELP G3FAX communicability (from 9.6 kbit/sec-14.4 kbit/sec FAX machine) 8 kbit/sec: TC-WVQ G3FAX communicability (7.2 kbit/sec)		
Features	Shared unit redundancy* Transmission line redundancy (automatic circuit backup capability during failure using INS network service) Free access to INS network (program port) Source clock switching Bypass function (audio: kbit/sec, data: 2.4 kbit/sec unit capability) Detection and display of transmission circuit and system abnormalities Simplified human-machine interface Circuit setting pattern switching		
Network management	Network management system (NMS) enables following management activities Alarm generated monitoring, operating status management, network setting management		
Function expendability	Software non-stop version upgrade feature enables functional upgrade without affecting circuits in operation Package plug-in system enables circuits to be easily expanded by field Active monitoring of standardization trends, e.g., TTC, ITU-TS, OSI		
Dimensions (W) x (D) x (H) mm	570 x 600 x 2000 (backspace conservable)	450 x 500 x 750	430 x 400 x 200
Maximum mainframe number	4		2 (basic and expansion unit)
Power supply	AC100V, DC-48V	AC100V	
Environmental conditions	Temperature: 5-40°C, humidity: 40-80 percent (avoid dew conditions)		
Cooling method	Fan cooling		Natural cooling
Power consumption	AC max 1.2 kW (1.4 kVA) (per unit)	Max 320 W (400 VA) (per unit)	Basic unit only: Max 100 W (130 VA)
	DC max 1.0 kW (1.4 kVA) (per unit)		Expansion unit: Max 190 W (230 VA)
Weight (not including cables)	Max 250 kg	Max 70 kg	Basic unit only: Max 20 kg
			Expansion unit: Max 40 kg

*: Not applicable to AD-8604

The time division multiplexer has been configured so that the internal control unit and telephone line system are independent of each other, with the primary aim being to assure reliability of the telephone lines. In addition, we have sought to decentralize the functions within the control unit as well. Accordingly, even if the emergency control system fails, it will be possible for the multiplexer to continue operating without any effect to the telephone line system, and for the circuits in service not to be affected even while functions are being expanded during operation (upgrade of the control system software, for example).

Next, we describe the functional features of the time division multiplexer.

(1) High-Efficiency Circuit Operation

The low-speed data systems that have been adopted for use in the multiplexer include a conventional ITU-T specified X.50 muliplexing system, and an even more high-efficiency multiplexing system (AHPM system) which we have developed in-house. This system enables the time division multiplexer to multiplex up to six channels of 9.6 kbit/sec lines per 64 kbit/s of information. The X.50 system can only go as high as five channels.

The audio system is provided with 8 kbit/sec, 16 kbit/sec, and 32 kbit/sec audio compression functions (CODEC system), which enables it to transmit a wide range of audio signals efficiently and with no loss of quality. This is particularly true of the 16 kbit/sec CODEC system that we have adopted, which is a ITU-T specified LD-CELP system. All of the CODEC systems, moreover, are capable of transmitting G3 facsimile signals. We have also been able to prevent poor audio quality, which had been a problem when doing multiple PBX audio broadcasts by in-house development of the digital 1-link method.

(2) Rich Array of Interfaces

The time division multiplexer is outfitted with a rich array of interfaces to handle such things as high-speed data, audio, high-speed digital circuits, and the INS network, and which enable it to accommodate a number of terminals and use such network services as a frame relay service.

(3) Use of Advanced INS Net Services

In this time division multiplexer, the INS network circuits serve two purposes, namely, as a backup during a digital circuit failure, and for free access when a bypass is needed during increased traffic. The access group of INS network circuits, which is capable of multiple registers per single INS network circuit, enables one INS network circuit to be used for a number of purposes such as backup and free access.

(4) Improved Maintainability and Operability

This is a feature of the system which enables a variety of the time division multiplexer operations to be performed with a notebook PC, including circuit settings and collecting and storing information on registers, operating status, and failures. It enables register information to be created off-line beforehand, and then downloaded to the multiplexers. The screen has a pop-up menu and a selection format makes it easy to use.

The various interface cable are all connected from the front of the multiplexer, which not only makes it easier to maintain but also saves space.

(5) Using NMS To Improve Network Management

The network management system (NMS) enables the operation, maintenance, and management of the entire TDM network to be done from a central location. The network management system that we adopted for the TDM is based on OSI management and enables a maximum of 127 nodes to be managed through one NMS system.

3. Element Technologies

In this section, we discuss the element technologies found inside the time division multiplexer.

3.1 Digital 1-Link Method

In time division multiplexers, it is customary to compress and multiplex audio signals in order to raise the utilization rate of SD circuits. There have been problems with poor audio quality, however, due to repeated audio encoding and decoding during relay exchanges in the case of large private communication networks made up of exchanges (PBX).

In order to solve this problem, engineers at Matsushita Communication have developed the digital 1-link method of audio transmission in which the relay between SD circuits is done with audio signals while they are compressed (Fig 3). In the past, this was achieved by the exchange communicating to the TDM either by decoding a compressed audio signal received from an SD circuit and sending that to the exchange, or by sending that while it is still compressed.

However, because the exchange and multiplexer needed special features in order to communicate with one another, the user was left with no recourse but to purchase the exchange from the same manufacturer as the multiplexer. That being the case, engineers here at Matsushita went ahead and developed the digital 1-link method that did not depend on the type of exchange, and put it into use with the time division multiplexer. Below, we describe this method in more detail.

(1) Identifying Relays

This is a method we developed of distinguishing audio signals that have been sent from the exchange from those that have come from telephones connected to the exchange and from those which the exchange has relayed one more time via the multiplexer.

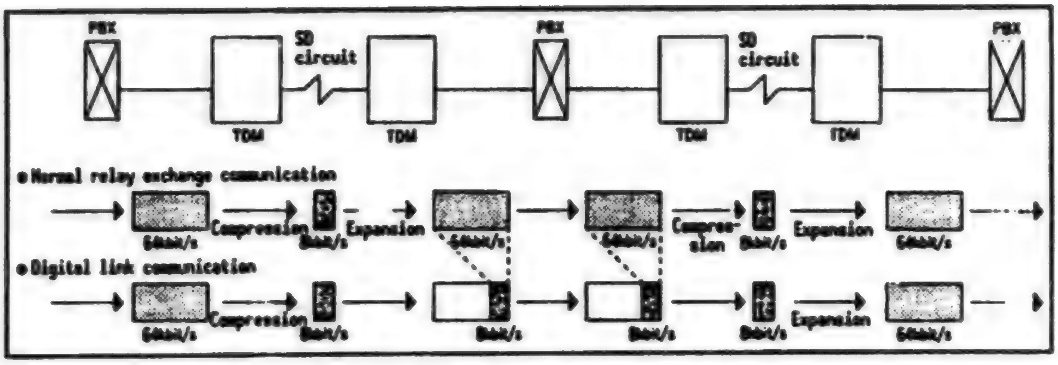

Fig 3. Conceptual Drawing of Digital 1-Link Method

(2) Decoded Audio Signal Format

When not a relayed transmission, a decoded 64 kbit/sec signal is sent to the exchange.

(3) Format With Digital 1-Link Transmission

The compressed signal is not decoded with a digital 1-link method configuration. This method uses a portion of the 64 kbit/sec signal with no difference in transmission speed after compression and outputs to the exchange. When that signal has been transmitted through the exchange, only the compressed signals are removed and passed along to the SD circuit.

3.2 Audio CODEC

In order to cut communication costs associated with private communication networks, companies have been strongly insisting on CODEC systems that offer better compression efficiency than ever before.

The time division multiplexer developed by Matsushita Communication offers an 8 kbit to 32 kbit/sec CODEC system that will meet the diverse needs of users. In Table 2, we offer a line-up of CODEC packages.

Table 2. CODEC Package

Audio encoding speed	Compression method	FAX transmission speed	Digital 1 link
32 kbit/sec	ADPCM	9.6 kbit/sec	No
16 kbit/sec	LD-CELP	14.4 kbit/sec	Yes
8 kbit/sec	TC-WVQ	7.2 kbit/sec	Yes

In the section below, we list the main features of audio CODEC in the time division multiplexer.

(1) Digital 1-Link Capability

This feature enables digital 1-link transmission without reliance on the type or functions of the exchange, thereby preventing poor audio quality caused by relay exchanges.

(2) Signaling In-Slot Capability

This feature enables signaling to be multiplexed and transmitted within compressed audio signals, and thereby achieves more effective multiplexing.

(3) Audio Compression Technology

Improvements in high-performance DSPs and compression technology have yielded CODEC systems with lower bit rates and better audio quality. The time division multiplexer described herein has a high-compression CODEC system that uses 16 kbit/sec LD-CELP and 8 kbit/sec TC-WVQ compression technology.

(4) G3FAX Capability

When low bit-rate audio compression technology was used, we were unable to transmit high-speed analog signals, and ran into problems with the FAX not being able to use the same lines as the telephone.

In order to resolve this problem in the time division multiplexer, we came up with a method of transmitting 14.4 kbit/sec FAX communications with 16 kbit/sec lines and 7.2 kbit/sec FAX communications with an 8 kbit/sec lines.

The point to note about this method of transmission is that by holding the processing delay between a group of CODEC systems to around 200 ms enabled a FAX communication to be transmitted even in networks where the audio is repeatedly compressed and extended.

3.3 Frame Relay (FR) Capability

The time division multiplexer that we have developed offers a frame relay function by being outfitted with an FR control package.

The FR control package, which has four interfaces that do not depend on the interface conditions of a layer one, relays frame data between the interfaces. These interfaces, which enable linkup with FR networks, FR terminals, other FR control packages, and bus-type LAN interface packages, can be used to construct an FR network having the features described below.

(1) Construction of Private FR Network

By interconnecting FR control packages via SD circuits, we were able to construct a logical private FR network (Fig 4). In order to achieve this, we have designed the interfaces (interoffice mode) connecting the FR packages with an OAM capability suited to internetwork connections.

The ability to mix and multiplex FR channels with other audio channels also enables us to select the optimum access speed to fit the volume of traffic.

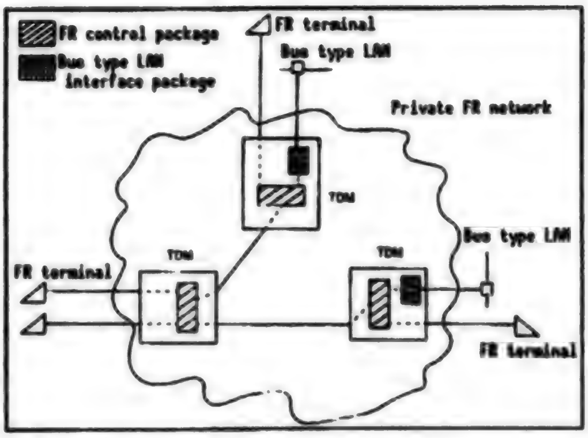

Figure 4. Construction of Private FR Network

(2) Interconnection Between Private FR Network and Public FR Network

This is an interconnecting configuration that enables a carrier from a private FR network to be transmitted to a public FR network (Fig 5).

To achieve this, the FR control package is supporting a UNI standardized to ITU-T, TTC, ANSI, and FR forum. It also has a feature that communicates to terminals of private FR networks that is not unlike carrier confirmation services or traffic notification services.

(3) Accommodation of Bus-Type LAN

LAN interconnections have been made more economical by offering a package having functions that enable the frame relay network to accommodate a bus-type LAN (ISO 8802/3 specified).

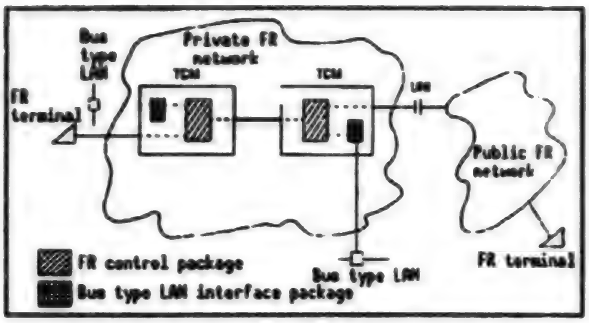

Figure 5. Interconnection Between Private FR Network and Public FR Network

These functions include a bus-type LAN bridging function and a function for capsulizing a frame of bus-type LAN to an FR network frame.

(4) High-Performance and Traffic Control

The FR control package has a high relay processing capability which is as fast as the access speed assigned to the interface. This enables the traffic control function, and existing SD circuits and public FR network to be used more efficiently. The FR control package manages the volume of communication data in interface units or PVC units that are set to that interface (CIR compliance). This stabilizes individual PVC communications so that other PVC with heavy traffic multiplexed on the same interface are not adversely affected during busy times and so that the data of PVC with other traffic is not discarded. When heavy traffic is detected using a public FR network service or the interoffice protocol of the FR control package, the terminal responsible for the heavy traffic is notified and traffic over the entire network is controlled.

3.4 Redundancy Methods

The time division multiplexer described herein has adopted the following architecture to help it improve system reliability.

(1) Redundancy of Internal Components

The most important components within the multiplexer, which are the common control unit, the clocking unit, the multiplex control unit, the digital circuit IF unit, and the power supply have all been designed with redundant configurations.

(2) Redundancy of Digital Circuits

In order to prevent a shutdown of network services due to a digital circuit failure, the multiplexer has been designed with the following digital circuit redundancies. In Fig 6, we show redundancy configurations of the digital circuits.

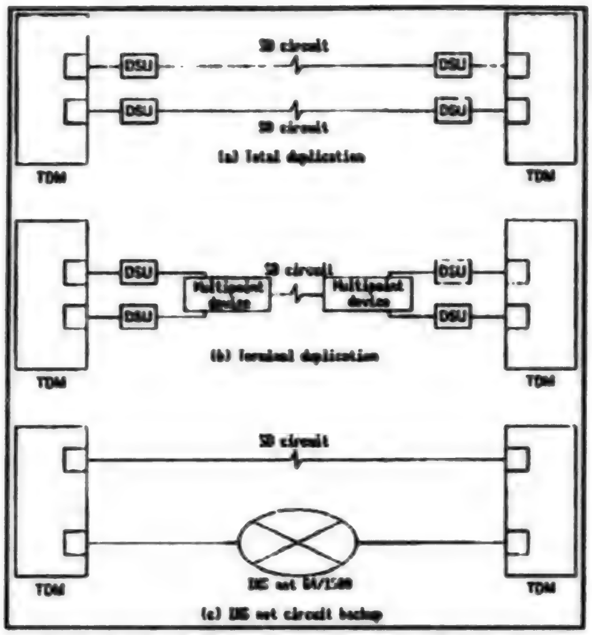

Fig 6. Redundancy Configurations of Digital Circuits

manages the circuits which connect the multiplexers with the NMS, and provides network users with a high quality and highly reliable network by making network operations more efficient and maintenance quicker.

4.1 Management System

The manager/agent system, which is based on OSI management, is being used as the management system and CMIP as the management protocol. The manager is responsible for the NMS and the agent is responsible for the option package used to manage the network of multiplexers. In Figure 7, we show a schematic drawing of the manager/agent model.

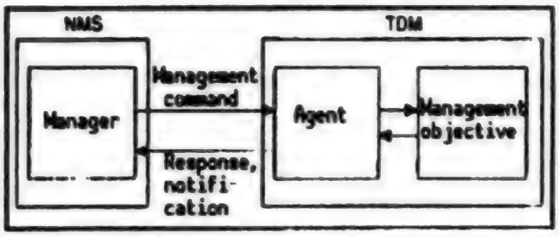

Fig 7. Manager/Agent Operation

CC1.DD Total Duplication by SD Circuits

This is a configuration in which two circuits are leased to create a redundant SD circuit.

CC2.DD Terminal Duplication by SD Circuits

This is a configuration in which a terminal multipoint service is used to create a redundant SD circuit.

CC3.DD Backup Using INS Net 64/1500

Here, an automatic backup of circuits is achieved by having the circuits automatically connected/detoured to an INS net 64/1500 whenever a failure of an SD circuit is detected. Backing up a number of SD circuits with one INS net 64/1500 enables the number of leased circuits to be reduced.

The backup by the INS network offers the advantage of being able to lower operating costs because communication is carried out despite a failure of the SD circuits. In the case of public networks, however, there are still instances where duplication of the SD circuits is used to achieve redundancy because of such problems as heavy traffic or security.

4. Network Management

The network management system (NMS) is basically a computer that is connected to a network system consisting of time division multiplexers, and which centrally

Below, we describe the information collection method used by the NMS.

The communication between the NMS and time division multiplexers is done by 8 kbit/sec and 2.4 kbit/sec time slots that are provided on the circuits that link the multiplexers.

The communication between the manager and agent is divided into the following two types.

(1) Communication From Agent to Manager

This is a system in which a primary TDM station collects node information by periodically polling secondary TDM stations and communicating that information as is to the NMS. This enables the manager to identify fault information and state change information. In Figure 8, we show the communication flow.

(2) Command From Manager to Agent

This is a format in which a command issued from a manager is converted to an internal TDM command (facility) within the agent and is then transmitted to the system control package of the TDM. This facility, which is the same as a command being sent from a command unit in the TDM, unifies control within the TDM by providing the exact same interface on the NMS side. In Figure 9, we show the command flow.

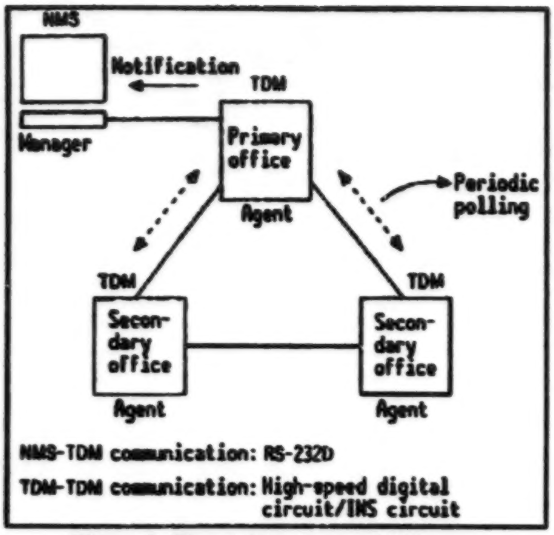

Figure 8. Signal Flow Toward Manager

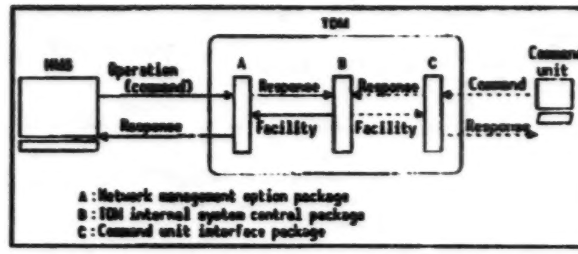

Fig 9. Signal Flow Toward Agent

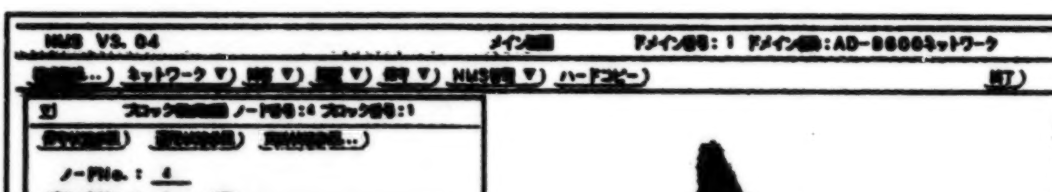

Fig 10. Typical Screen From Network Management System

4.2 Management Functions

In Figure 10, we show a typical screen of the network management system, and in Table 3 we list the main specifications of the system.

Table 3. Specifications of Network Management System

No. of supervisory TDM	—Maximum 127
Configuration management functions	—Editing of configuration data —Input/output of configuration data —Displaying configuration data —Uploading-downloading configuration data
Fault management functions	—Fault detection display —Calculate/display/print out statistical data
Performance management functions	—Frame relay traffic display
Accounting management functions	—Calculate/display INS net services information
Operation/maintenance functions	—Circuit switching —Duplication switching —Reset —Maintenance and testing capability
Logging functions	—Collect, display, output historical information
Other functions	—Backup of management paths —Remote control function (remote control function enables network to be supervised from private monitoring or supervisory control NMS installed in a remote location)

5. Conclusion

As we discussed in the foregoing paper, Matsushita Communication has achieved the needed functions to build a private corporate communication network with AD-8600 series multimedia time division multiplexers. In the future, the company plans to work toward enhancing these functions even further to meet the needs of new communication systems.

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